



# NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA



CATALOGUE FOR 1967-1968





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*CATALOGUE FOR 1967-1968*



ROBERT STRANGE MCNAMARA  
Secretary of Defense



## MISSION

The Secretary of the Navy has defined the mission of the Naval Postgraduate School as follows:

“To conduct and direct the Advanced Education of commissioned officers, to broaden the professional knowledge of general line officers, and to provide such other indoctrination, technical and professional instruction as may be prescribed to meet the needs of the Naval Service; and in support of the foregoing, to foster and encourage a program of research in order to sustain academic excellence.”



Superintendent  
EDWARD JOSEPH O'DONNELL  
Rear Admiral, U.S. Navy  
B.S., Naval Academy, 1929; Naval Postgraduate School, 1939



Academic Dean

ROBERT FROSS RINEHART

B.A., Wittenberg College, 1930;

M.A., Ohio State Univ., 1932;

Ph.D., 1934; D.Sc., Wittenberg Univ., 1960



*Main Entrance to Postgraduate School*

## NAVAL POSTGRADUATE SCHOOL

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### Deputy Superintendent for Operations and Programs

WILLIAM HAROLD LIVINGSTON

Captain, U.S. Navy

B.S. in A.E., Naval Postgraduate School, 1949;

M.S. in A.E., Princeton, 1950

### Deputy Superintendent for Administration and Logistics

THOMAS ANDREW MELUSKY

Captain, U.S. Navy

B.S., Univ. of Washington, 1941;

M.A., George Washington Univ., 1963

### Dean of Programs

WILBERT FREDERICK KOEHLER

B.S., Allegheny College, 1933; M.A.,

Cornell Univ., 1934; Ph.D., Johns Hopkins Univ., 1948

### Executive Assistant to the Deputy Superintendent for Operations and Programs

WILLIAM AMBROSE PITCHER

Captain, U.S. Navy

B.A., San Jose State College, 1938

### Dean of Curricula

BROOKS JAVINS LOCKHART

B.A., Marshall Univ., 1937; M.S., West

Virginia Univ., 1940; Ph.D., Univ. of Illinois, 1943

### Dean of Research Administration

CARL ERNEST MENNEKEN

B.S., Univ. of Florida, 1932;

M.S., Univ. of Michigan, 1936

## SUPERINTENDENT'S STAFF ASSISTANTS

Aide to the Superintendent.....LT GREGORY DANIEL FITZPATRICK, USN  
 Comptroller.....CAPT EDWARD A. SANFORD, JR., SC, USN  
 Industrial Relations Officer.....MR. JOHN J. COYLE  
 Aviation Officer (CO, NALF).....CAPT MARK TWAIN WHITTIER, USN  
 Senior Medical Officer (NALF).....CAPT NEIL V. WHITE, MC, USN

## DEAN OF CURRICULA STAFF

Registrar.....MRS. BESSIE WILK  
 Class Scheduler.....MRS. JACQUELINE M. OLSON  
 Cataloguer.....MRS. MARY KLOTZ BURTON

## OPERATIONS AND PROGRAMS ADMINISTRATIVE STAFF

Plans Officer.....CDR WARREN A. HIGLEY, USN  
 Flight Officer.....CDR EDWARD D. JACKSON, USN  
 Administrative Officer.....LCDR NANCY L. DENTON, USN  
 Program Allotment and  
   Material Control Officer.....LCDR DEROY L. HANSON, USN  
 Academic Liaison Officer.....LCDR MAXINE A. MANDT, USN  
 Foreign Training Officer.....CDR JOSEPH P. LEO, JR., USN  
 Marine Corps Representative.....LT COL EDWIN M. RUDZIS, USMC  
 Submarine Liaison Officer.....CDR BOONE C. TAYLOR, USN

## ADMINISTRATION AND LOGISTICS STAFF

Head, Administration Dept.....CDR ROBERT L. PELTON, USN  
 Head, Supply Dept.....CDR MARY J. APLIN, SC, USN  
 Head, Public Works Dept.....CAPT WAYNE S. MITTER, CEC, USN  
 Head, Dental Dept.....CAPT EDMUND H. FRIZZELL, DC, USN  
 Head, Services Department.....CDR EVERETT R. PEUGH, USN  
 Catholic Chaplain.....CAPT FRANCIS J. FITZPATRICK, ChC, USN  
 Protestant Chaplain.....CAPT SAMUEL D. CHAMBERS, ChC, USN  
 Public Affairs & Visit Liaison.....LCDR JOHN A. WIDDER, JR., USN  
 Legal Officer.....LCDR LARRY W. GRESENS, USNR  
 Communications Officer.....LT RONALD J. McAFEE, USN  
 Staff Secretary.....LT DONALD E. TOWNE, USN



## CALENDAR FOR 1967-68 ACADEMIC YEAR

1967

Date for Final Completion of Thesis for July Graduation.....	Thursday, 22 June
Registration for Management, BS/BA, Nuclear Engineering (Effects) Curricula.....	Monday, 26 June
Quarter I Begins.....	Monday, 3 July
Fourth of July (Holiday).....	Tuesday, 4 July
Graduation.....	Thursday, 6 July
Refresher Course Begins.....	Monday, 14 August
Labor Day (Holiday).....	Monday, 4 September
Date for Final Completion of Thesis for September Graduation.....	Wednesday, 13 September
Registration for all Curricula, except Management, BS/BA, Nuclear Engineering (Effects).....	Monday, 18 September
Exam Week for Quarter I.....	18-22 September
Quarter I Ends.....	Friday, 22 September
Quarter II Begins.....	Monday, 25 September
Graduation.....	Wednesday, 27 September
Language Exam in French, German, Russian, for Ph.D. Candidates.....	Monday, 23 October
Veterans Day (Holiday).....	Friday, 10 November
Thanksgiving Day (Holiday).....	Thursday, 23 November
Date for Final Completion of Thesis for December Graduation.....	Wednesday, 6 December
Exam Week for Quarter II.....	11-15 December
Quarter II Ends.....	Friday, 15 December
Christmas Holiday Begins.....	Monday, 18 December
Graduation.....	Wednesday, 20 December
Registration for Management, BS/BA Curricula.....	Tuesday, 26 December

1967

JANUARY							JULY						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
1	2	3	4	5	6	7							1
8	9	10	11	12	13	14		2	3	4	5	6	7
15	16	17	18	19	20	21		8	9	10	11	12	13
22	23	24	25	26	27	28		14	15	16	17	18	19
29	30	31						20	21	22	23	24	25
								26	27	28	29	30	31
FEBRUARY							AUGUST						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
			1	2	3	4			1	2	3	4	5
5	6	7	8	9	10	11		6	7	8	9	10	11
12	13	14	15	16	17	18		12	13	14	15	16	17
19	20	21	22	23	24	25		18	19	20	21	22	23
26	27	28						24	25	26	27	28	29
MARCH							SEPTEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
			1	2	3	4						1	2
5	6	7	8	9	10	11		3	4	5	6	7	8
12	13	14	15	16	17	18		9	10	11	12	13	14
19	20	21	22	23	24	25		15	16	17	18	19	20
26	27	28	29	30	31			21	22	23	24	25	26
APRIL							OCTOBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
						1			1	2	3	4	5
2	3	4	5	6	7	8		6	7	8	9	10	11
9	10	11	12	13	14	15		12	13	14	15	16	17
16	17	18	19	20	21	22		18	19	20	21	22	23
23	24	25	26	27	28	29		24	25	26	27	28	29
30								29	30	31			
MAY							NOVEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
			1	2	3	4				1	2	3	4
5	6	7	8	9	10	11		5	6	7	8	9	10
12	13	14	15	16	17	18		11	12	13	14	15	16
19	20	21	22	23	24	25		17	18	19	20	21	22
26	27	28	29	30	31			24	25	26	27	28	29
JUNE							DECEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
				1	2	3						1	2
4	5	6	7	8	9	10		3	4	5	6	7	8
11	12	13	14	15	16	17		9	10	11	12	13	14
18	19	20	21	22	23	24		15	16	17	18	19	20
25	26	27	28	29	30			21	22	23	24	25	26
								28	29	30	31		

1968

1968

JANUARY							JULY						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
1	2	3	4	5	6	7		1	2	3	4	5	6
7	8	9	10	11	12	13		7	8	9	10	11	12
14	15	16	17	18	19	20		14	15	16	17	18	19
21	22	23	24	25	26	27		21	22	23	24	25	26
28	29	30	31					28	29	30	31		
FEBRUARY							AUGUST						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
						1							1
4	5	6	7	8	9	10		4	5	6	7	8	9
11	12	13	14	15	16	17		11	12	13	14	15	16
18	19	20	21	22	23	24		18	19	20	21	22	23
25	26	27	28	29				25	26	27	28	29	30
MARCH							SEPTEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
						1							1
3	4	5	6	7	8	9		3	4	5	6	7	8
10	11	12	13	14	15	16		10	11	12	13	14	15
17	18	19	20	21	22	23		17	18	19	20	21	22
24	25	26	27	28	29	30		24	25	26	27	28	29
31								31					
APRIL							OCTOBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
						1							1
2	3	4	5	6	7	8		2	3	4	5	6	7
9	10	11	12	13	14	15		9	10	11	12	13	14
16	17	18	19	20	21	22		16	17	18	19	20	21
23	24	25	26	27	28	29		23	24	25	26	27	28
30								30					
MAY							NOVEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
						1							1
2	3	4	5	6	7	8		2	3	4	5	6	7
9	10	11	12	13	14	15		9	10	11	12	13	14
16	17	18	19	20	21	22		16	17	18	19	20	21
23	24	25	26	27	28	29		23	24	25	26	27	28
30								30					
JUNE							DECEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
						1							1
2	3	4	5	6	7	8		2	3	4	5	6	7
9	10	11	12	13	14	15		9	10	11	12	13	14
16	17	18	19	20	21	22		16	17	18	19	20	21
23	24	25	26	27	28	29		23	24	25	26	27	28
30								30					

Quarter III Begins.....	Tuesday, 2 January
Language Exam in French, German, Russian, for Ph.D. Candidates.....	Monday, 22 January
Refresher Course Begins.....	Monday, 12 February
Washington's Birthday (Holiday).....	Thursday, 22 February
Date for Final Completion of Thesis for March Graduation.....	Wednesday, 13 March
Registration for all Curricula, except Management, BS/BA, CEC Electronics, Nuclear Engineering (Effects), Underwater Physics Systems.....	Monday, 18 March
Exam Week for Quarter III.....	18-22 March
Quarter III Ends.....	Friday, 22 March
Quarter IV Begins.....	Monday, 25 March
Graduation.....	Wednesday, 27 March
Language Exam in French, German, Russian, for Ph.D. Candidates.....	Monday, 22 April
Refresher Course Begins.....	Monday, 20 May
Memorial Day.....	Thursday, 30 May
Date for Final Completion of Thesis for June Graduation.....	Wednesday, 5 June
Exam Week for Quarter IV.....	10-14 June
Quarter IV Ends (1967-68).....	Friday, 14 June
Graduation.....	Friday, 21 June
Registration for Management, BS/BA, Nuclear Engineering (Effects) Curricula.....	Monday, 24 June
Quarter I Begins (1968-69).....	Monday, 1 July
Fourth of July (Holiday).....	Thursday, 4 July
Refresher Course Begins.....	Monday, 12 August
Labor Day.....	Monday, 2 September
Date for Final Completion of Thesis for September Graduation.....	Wednesday, 11 September
Registration for all Curricula, except Management, BS/BA, Nuclear Engineering (Effects).....	Monday, 16 September
Exam Week for Quarter I.....	16-20 September
Quarter I Ends.....	Friday, 20 September
Quarter II Begins.....	Monday, 23 September
Graduation.....	Wednesday, 25 September





*Paul H. Nitze, Secretary of the Navy, and Rear Admiral E. J. O'Donnell, Superintendent,  
with Distinguished Professors Giet, Duthie, Coates, and Mewborn*

## DISTINGUISHED ALUMNI

Among those who have completed a Naval Postgraduate School curriculum who attained flag (USN) or general (USMC) rank on the active list are the following: (The asterisk (\*) indicates those on active list as of 1 January 1967.)

Admiral Walter F. Boone	Vice Admiral Ephraim P. Holmes*	Vice Admiral Aurelius B. Voseller
Admiral Arleigh A. Burke	Vice Admiral George F. Hussey, Jr.	Vice Admiral Homer N. Wallin
General Clifton B. Cates	Vice Admiral Olaf M. Hustvedt	Vice Admiral James H. Ward
Admiral Maurice E. Curtis	Vice Admiral Thomas B. Inglis	Vice Admiral Charles E. Weakley*
Admiral Robert L. Dennison	Vice Admiral Robert W. Hayler	Vice Admiral Charles Wellborn, Jr.
Admiral Donald B. Duncan	Vice Admiral Andrew M. Jackson, Jr.*	Vice Admiral George L. Weyler
Admiral Frank G. Fahrion	Vice Admiral Albert E. Jarrell	Vice Admiral Charles W. Wilkins
Admiral Cato D. Glover, Jr.	Vice Admiral Harry B. Jarrett	Vice Admiral Ralph E. Wilson
Admiral Roscoe F. Good	Lieutenant General Clayton C. Jerome	Vice Admiral George C. Wright
Admiral Charles D. Griffin*	Vice Admiral Robert T. S. Keith	Rear Admiral John W. Ailes, III
Admiral Byron H. Hanlon	Vice Admiral Ingolf N. Kiland	Rear Admiral Frank Akers
Admiral Royal E. Ingersoll	Vice Admiral Fred P. Kirtland	Rear Admiral Roy G. Anderson*
Admiral Albert G. Noble	Vice Admiral Harold O. Larson	Rear Admiral Jackson D. Arnold*
Admiral Alfred M. Pride	Vice Admiral Ruthven E. Libby	Rear Admiral Frederick L. Ashworth*
Admiral James O. Richardson	Vice Admiral Vernon L. Lowrance*	Rear Admiral Edgar H. Batcheller*
Admiral Horacio Rivero, Jr.*	Vice Admiral James E. Maher	Rear Admiral Richard W. Bates
Admiral Samuel M. Robinson	Vice Admiral William J. Marshall	Rear Admiral Frederick J. Becton
Admiral James S. Russell	Vice Admiral Charles B. Martell*	Rear Admiral David B. Bell*
Admiral Ulysses S. G. Sharp, Jr.*	Vice Admiral Kleber S. Masterson*	Rear Admiral Fred G. Bennett*
Admiral John H. Sides	Vice Admiral John L. McCrea	Rear Admiral Rawson Bennett, II
General Holland M. Smith	Vice Admiral Ralph E. McShane	Rear Admiral Philip A. Beshany*
Admiral Felix B. Stump	Vice Admiral Charles L. Melson	Rear Admiral Abel T. Bidwell
General Merrill B. Twining	Vice Admiral Arthur C. Miles	Major General Arthur F. Binney
Admiral Alfred G. Ward*	Vice Admiral Earle W. Mills	Rear Admiral Calvin M. Bolster
Admiral John M. Will	Vice Admiral Marion E. Murphy	Rear Admiral Frank A. Braisted
Vice Admiral Walter S. Anderson	Vice Admiral Lloyd M. Mustin*	Rear Admiral Harold M. Briggs
Vice Admiral Harold D. Baker	Vice Admiral Frank O'Beirne	Rear Admiral William A. Brockett
Vice Admiral Wallace M. Beakley	Vice Admiral Francis P. Old	Rear Admiral Charles B. Brooks, Jr.
Vice Admiral George F. Beardsley	Vice Admiral Howard E. Orem	Rear Admiral James A. Brown*
Vice Admiral Frank E. Beatty	Vice Admiral Harvey E. Overesch	Rear Admiral Henry C. Bruton
Vice Admiral Robert E. Blick, Jr.	Vice Admiral Edward N. Parker	Rear Admiral Charles A. Buchanan
Vice Admiral Charles T. Booth, II*	Vice Admiral Frederick W. Pennoyer, Jr.	Rear Admiral Thomas Burrowes
Vice Admiral Roland M. Brainard	Vice Admiral Charles A. Pownall	Rear Admiral Robert L. Campbell
Vice Admiral Carleton F. Bryant	Vice Admiral Thomas C. Ragan	Rear Admiral Milton O. Carlson
Vice Admiral William M. Callaghan	Vice Admiral Lawson P. Ramage*	Rear Admiral Worrall R. Carter
Vice Admiral John H. Carson	Vice Admiral William L. Rees	Rear Admiral Robert W. Cavenagh
Vice Admiral Ralph W. Christie	Vice Admiral Robert H. Rice	Rear Admiral Lester S. Chambers
Vice Admiral Oswald S. Colclough	Vice Admiral Hyman G. Rickover*	Rear Admiral John L. Chew*
Vice Admiral John B. Colwell*	Vice Admiral Rufus E. Rose	Rear Admiral Ernest E. Christensen*
Vice Admiral Thomas F. Connolly*	Vice Admiral Richard W. Ruble	Rear Admiral David H. Clark
Vice Admiral George R. Cooper	Vice Admiral Theodore D. Ruddock, Jr.	Rear Admiral Henry G. Clark, CEC
Vice Admiral William G. Cooper	Vice Admiral Lorenzo S. Sabin, Jr.	Rear Admiral Sherman R. Clark
Vice Admiral John C. Daniel	Vice Admiral Harry Sanders	Rear Admiral Leonidas D. Coates, Jr.
Vice Admiral Glenn B. Davis	Vice Admiral Walter G. Schindler	Rear Admiral Howard L. Collins
Vice Admiral Harold T. Deutermann	Vice Admiral William A. Schoech	Rear Admiral Joshua W. Cooper
Vice Admiral Glynn R. Donaho*	Vice Admiral Harry E. Sears	Rear Admiral Roy T. Cowdrey
Vice Admiral James H. Doyle	Vice Admiral Thomas G. W. Settle	Rear Admiral Ormond L. Cox
Vice Admiral Irving T. Duke	Vice Admiral William B. Smedberg, III	Rear Admiral Richard S. Craighill*
Vice Admiral Ralph Earle, Jr.	Vice Admiral Allan E. Smith	Rear Admiral Frederick G. Crisp
Vice Admiral Clarence E. Ekstrom	Vice Admiral Chester C. Smith	Rear Admiral Robert E. Cronin
Vice Admiral Emmet P. Forrestel	Vice Admiral Roland N. Smoot	Rear Admiral Charles A. Curtze
Vice Admiral Roy A. Gano	Lieutenant General Edward W. Snedeker	Rear Admiral John E. Dacey*
Vice Admiral William E. Gentner, Jr.*	Vice Admiral Selden B. Spangler	Rear Admiral James A. Dare*
Vice Admiral Elton W. Grenfell	Vice Admiral Thomas M. Stokes	Rear Admiral Lawrence R. Daspit*
Lieutenant General Field Harris	Vice Admiral Paul D. Stroop	Rear Admiral James R. Davis, CEC
Vice Admiral Truman J. Hedding	Lieutenant General James A. Stuart	Rear Admiral James W. Davis
Lieutenant General Geo. D. Hermle	Vice Admiral Wendell G. Switzer	Rear Admiral James C. Dempsey*
Vice Admiral Ira E. Hobbs	Vice Admiral John Sylvester	Rear Admiral Vincent P. de Poix*



Rear Admiral Ernest W. Dobie, Jr.*	Major General Frank H. Lamson-Scribner	Rear Admiral Malcolm F. Schoeffel
Rear Admiral Joseph E. Dodson	Rear Admiral Martin J. Lawrence	Rear Admiral Floyd B. Schultz*
Rear Admiral William A. Dolan, Jr.	Rear Admiral William H. Leahy	Rear Admiral John N. Shaffer*
Rear Admiral Marshall E. Dornin*	Rear Admiral William E. Lemos*	Rear Admiral William B. Sieglaff
Rear Admiral Jack S. Dorsey*	Rear Admiral Joseph W. Leverton, Jr.	Rear Admiral Harry Smith
Rear Admiral Jennings B. Dow	Rear Admiral John K. Leydon*	Rear Admiral John V. Smith*
Rear Admiral Louis Dreher	Rear Admiral Theodore C. Lonquest	Rear Admiral Levering Smith*
Rear Admiral Norman J. Drustup, CEC*	Rear Admiral Almon E. Loomis	Rear Admiral John A. Snackenber
Rear Admiral Clifford H. Duerfeldt	Rear Admiral Wayne R. Loud	Rear Admiral Philip W. Snyder
Rear Admiral Donald T. Eller	Rear Admiral Charles H. Lyman, III	Rear Admiral Edward A. Solomons
Rear Admiral Robert B. Ellis	Major General William G. Manley	Rear Admiral Robert H. Speck*
Rear Admiral Edward J. Fahy*	Rear Admiral Charles F. Martin	Rear Admiral Frederick C. Stelter, Jr.
Rear Admiral James M. Farrin, Jr.	Major General Keith B. McCutcheon*	Rear Admiral Edward C. Stephan
Rear Admiral Emerson E. Fawkes*	Rear Admiral John B. McGovern	Rear Admiral Earl E. Stone
Rear Admiral John J. Fee*	Rear Admiral Eugene B. McKinney	Rear Admiral Charles W. Styer
Rear Admiral William E. Ferrall	Rear Admiral Kenmore M. McManes	Rear Admiral Robert L. Swart
Rear Admiral Charles W. Fisher	Rear Admiral Robert W. McNitt*	Rear Admiral William E. Sweeney*
Rear Admiral Eugene B. Fluckey*	Rear Admiral John H. McQuilken*	Rear Admiral Frank R. Talbot
Rear Admiral Mason B. Freeman*	Rear Admiral Wm. K. Mendenhall, Jr.	Rear Admiral Raymond D. Tarbuck
Rear Admiral Laurence H. Frost	Major General Lewie G. Merritt	Rear Admiral Arthur H. Taylor
Rear Admiral Robert B. Fulton, II*	Rear Admiral Frederick H. Michaelis*	Rear Admiral John McN. Taylor*
Rear Admiral Daniel V. Gallery	Rear Admiral William Miller	Rear Admiral Theodore A. Torgerson
Rear Admiral Fillmore B. Gilkeson*	Rear Admiral Benjamin E. Moore	Rear Admiral George C. Townner
Rear Admiral Robert O. Glover	Rear Admiral Robert L. Moore, Jr.	Rear Admiral Robert L. Townsend*
Rear Admiral Alexander S. Goodfellow, Jr.*	Rear Admiral Armand M. Morgan	Rear Admiral David M. Tyree
Rear Admiral Willard K. Goodney	Rear Admiral Thomas H. Morton	Rear Admiral Frank Virden
Rear Admiral Arthur R. Gralla*	Rear Admiral Albert G. Mumma	Rear Admiral John R. Wadleigh*
Rear Admiral Lucien McK. Grant	Rear Admiral William T. Nelson	Rear Admiral George H. Wales
Rear Admiral Edward E. Grimm*	Rear Admiral Charles A. Nicholson, II	Rear Admiral Thomas J. Walker, III*
Rear Admiral Peter W. Haas, Jr.	Rear Admiral Robert H. Northwood, SC	Rear Admiral Frederick B. Warder
Rear Admiral Ira F. Haddock, SC*	Rear Admiral Ira H. Nunn	Rear Admiral William W. Warlick
Rear Admiral Frederick E. Haeberle	Rear Admiral Emmet O'Beirne	Rear Admiral Odale D. Waters, Jr.*
Rear Admiral Wesley M. Hague	Rear Admiral Edward J. O'Donnell*	Rear Admiral Hazlett P. Weatherwax
Rear Admiral Grover B. H. Hall	Rear Admiral Clarence E. Olsen	Rear Admiral Thomas R. Weschler*
Rear Admiral Lloyd Harrison	Rear Admiral Ernest M. Pace	Rear Admiral Ralph Weymouth*
Rear Admiral Hugh E. Haven	Rear Admiral Charles J. Palmer	Rear Admiral Charles D. Wheelock
Rear Admiral Frederick V. H. Hilles	Rear Admiral Lewis S. Parks	Rear Admiral Francis T. Williamson
Rear Admiral Wellington T. Hines	Rear Admiral Goldsborough S. Patrick	Rear Admiral Frederick S. Withington
Rear Admiral Morris A. Hirsch*	Rear Admiral John B. Pearson, Jr.	Rear Admiral Edward A. Wright
Rear Admiral George A. Holderness, Jr.	Rear Admiral Henry S. Persons*	Rear Admiral Howard A. Yeager*
Rear Admiral Paul A. Holmberg*	Rear Admiral William F. Petrovic*	Rear Admiral Elmer E. Yeomans
Rear Admiral Ralston S. Holmes	Rear Admiral Carl J. Pfingstag	Brigadier General George C. Axtell, Jr.*
Rear Admiral Ernest C. Holtzworth	Rear Admiral Richard H. Phillips	Commodore Harry A. Badt
Rear Admiral Leroy V. Honsinger	Rear Admiral Ben B. Pickett*	Commodore Harold Dodd
Rear Admiral Edwin B. Hooper*	Rear Admiral Paul E. Pihl	Brigadier General Edward C. Dyer
Rear Admiral Harold A. Houser	Rear Admiral Frank L. Pinney, Jr.*	Brigadier General Jacob E. Glick*
Rear Admiral Herbert S. Howard	Rear Admiral Walter H. Price	Commodore Stanley D. Jupp
Rear Admiral Miles H. Hubbard	Rear Admiral Schuyler N. Pyne	Brigadier General Ivan W. Miller
Rear Admiral Harry Hull*	Rear Admiral Joseph R. Redman	Commodore Robert E. Robinson, Jr.
Rear Admiral James McC. Irish	Rear Admiral Harry L. Reiter, Jr.*	Commodore Henry A. Schade
Rear Admiral William D. Irvin*	Rear Admiral Henry A. Renken*	Commodore Oscar Smith
Rear Admiral Joseph A. Jaap	Rear Admiral Joseph E. Rice*	Commodore Ralph S. Wentworth
Major General Samuel S. Jack	Rear Admiral Lawrence B. Richardson	<i>Rear Admiral Selectees:</i>
Major General Arnold W. Jacobsen	Rear Admiral Basil N. Rittenhouse, Jr.	CAPT Roger W. Paine, Jr.*
Rear Admiral Ralph K. James	Rear Admiral Walter F. Rodee	CAPT James H. Smith, Jr.*
Rear Admiral Frank L. Johnson*	Rear Admiral William K. Romoser	CAPT Kenan C. Childers, Jr.*
Rear Admiral Horace B. Jones, CEC	Rear Admiral Gordon Rowe	CAPT Francis J. Fitzpatrick*
Rear Admiral Husband E. Kimmel	Rear Admiral Donald Royce	CAPT William R. McKinney*
Rear Admiral Denys W. Knoll*	Rear Admiral Edward A. Ruckner*	CAPT Roderick O. Middleton*
Rear Admiral Sydney M. Kraus	Rear Admiral Thomas J. Rudden, Jr.*	CAPT Raymond E. Peet*
Rear Admiral Thomas R. Kurtz, Jr.	Rear Admiral George L. Russell	CAPT Mark W. Woods*
Rear Admiral David Lambert*	Rear Admiral Ben W. Sarver*	CAPT Paul L. Lacy, Jr.*

## HISTORY

The Naval Postgraduate School had a modest beginning at the Naval Academy at Annapolis in 1909, at which time the first class of ten officers enrolled in a Marine Engineering curriculum. The need for technically educated officers had become evident at the turn of the century. The idea of a naval graduate school had its inception in a course of instruction in Marine Engineering which the Bureau of Engineering instituted in 1904. The results of this course were so encouraging that in 1909 the Secretary of the Navy established a School of Marine Engineering at the Naval Academy in Annapolis. In 1912 the School was designated the Postgraduate Department of the Naval Academy.

The operation of the school was temporarily suspended during World War I, but in 1919 classes were resumed in converted Marine Barracks on the Naval Academy grounds. At this time curricula in Mechanical Engineering and Electrical Engineering were added. With the passing years other curricula — Ordnance Engineering, Radio Engineering, Aerological Engineering and Aeronautical Engineering — were added as the Navy's need for officers with technical knowledge in these fields became evident.

In 1927 the General Line Curriculum was established within the Postgraduate School to provide courses of instruction to acquaint junior line officers returning from sea duty with modern developments taking place in the Navy. The courses dealt with naval and military subjects for the most part. The General Line Curriculum remained as an integral part of the Postgraduate Department until the declaration of the emergency prior to the outbreak of World War II, at which time it was discontinued because of the need for officers in the growing fleet.

The enrollment in the Postgraduate School increased rapidly in the war years both in the several engineering curricula and in the communications curriculum which was added to meet the need for trained communication officers in the naval establishment. The School outgrew its quarters necessitating the building of an annex to house the additional classrooms and laboratories required, but even with this addition, the space requirements of the expanded school were not met.

The post-war program called for still further ex-

pansion and the re-establishment of the General Line Curriculum with a greatly increased enrollment. In 1946 the General Line School was established at Newport, Rhode Island, as an outlying element of the Postgraduate School and continued until disestablished in 1952; in 1948 an additional General Line School was established at Monterey, California. The objective of the General Line School program — that of providing an integrated course in naval science to broaden the professional knowledge of unrestricted line officers of the Regular Navy — continued in effect as it had since the inception of this program. During the period 1946 to 1955 the School served to provide such education primarily to Reserve and ex-Temporary officers who had transferred to Regular status.

The physical growth of the School and its increase in scope and importance were recognized in Congressional action which resulted in legislation during the years of 1945 to 1951 emphasizing the academic stature of the School, and providing for continued growth in a new location with modern buildings and equipment. This legislation authorized the Superintendent to confer Bachelor's, Master's, and Doctor's degrees in engineering and related subjects; created the position of Academic Dean to insure continuity in academic policy; established the School as a separate naval activity to be known as the Naval Postgraduate School; authorized the establishment of the School at Monterey, California; provided funds to initiate the construction of buildings to house modern laboratories and classrooms at that location.

On 22 December 1951, by order of the Secretary of the Navy, the Naval Postgraduate School was officially disestablished at Annapolis, Maryland, and established at Monterey, California. This completed the transfer of the School from the East to the West Coast, which had begun in 1948 when the Aerology Department and Curricular office were moved to the new location. Concurrently with this relocation the Naval School (General Line) at Monterey was disestablished as a separate military command and it became a component of the Naval Postgraduate School. At the same time, there was established the Naval Administrative Command, Naval Postgraduate School, Monterey, to provide logistic support, including supply, public works, medical and dental

functions, for the Naval Postgraduate School and its components.

In June 1956, by direction of the Chief of Naval Personnel, the Navy Management School was established as an additional component of the Postgraduate School. Its mission was to provide an educational program for officers in the application of sound scientific management practice to the complex organizational structure and operation of the Navy with a view to increasing efficiency and economy of operation. The first class included only Supply and Civil Engineering Corps officers and emphasis was placed on general management theory, financial management, and inventory management. In August 1957 this school was expanded to include input of both Line and Staff Corps officers. Since that time the curriculum has been under constant revision to include new areas of import to, and changes of concept in, the field of management. Subsequently the curriculum was lengthened and led to a master's degree for those who could meet the requirements for such a degree.

Discussions commenced in mid-1957 resulted in the establishment in August, 1958, of a Bachelor of Science curriculum in the General Line School and a change in the name of that school, effective 1 July 1958, to the General Line and Naval Science School.

The curriculum included subjects taught in the General Line curriculum plus new courses adequate in number, level, and scope to support a degree of bachelor of science, no major designated. The success of the program through the early classes led to the addition of an Arts program in August 1961 to provide for those officers whose previous education emphasized the humanities rather than science and mathematics.

These baccalaureate curricula eventually replaced the Navy's Five-Term Program which had been conducted in civilian universities and, except for the College Degree Program, now constitute the only programs available to naval officers to complete their undergraduate education.

In August 1960 the Engineering Science Curriculum was initiated with a concurrent reduction in the number of U. S. officers enrolled in the General Line Curriculum. In August 1962 input of U. S. officers into the General Line Curriculum was terminated; however, the program was continued for foreign naval officers.

The continuing growth and projected expansion of the School led to a major reorganization in 1962. In June, the Administrative Command was disestablished as a separate command, its functions continuing to be performed by personnel reporting to a new Director of Administrative and Logistic Services. In August, the three component schools were disestablished and a completely new organization became effective. There is now but one School — the Naval Postgraduate School — with unified policy, procedure, and purpose. The position of Chief of Staff was replaced by Deputy Superintendent and responsibility for the operation of all academic programs was placed under the dual control of a naval officer Director of Programs and a civilian Dean of Programs.

A subsequent reorganization in 1966 resulted in the disestablishment of the position of Deputy Superintendent and the retitling of the positions of the principal military assistants as will be noted in the following section.

In January 1967 after a thorough reevaluation and revision of curricula in the light of curricular objectives, plans were approved to shift the operations of the School from a five-term to a four-quarter academic calendar effective 1 July 1967. This will result in certain personnel economies, and in the overall strengthening of curricula by the elimination of obsolete and unnecessary material and realignment of course content into more logical sequence.

In connection with the foregoing, the General Line Curriculum for foreign officers and the Naval Warfare Department are being disestablished. Foreign officers will continue to be enrolled in the technical and management curricula. Those courses in naval professional subjects previously offered by the Naval Warfare Department for U. S. officer students in the Baccalaureate Curriculum will be transferred to other existing academic departments.

## ORGANIZATION AND FUNCTIONS

The Superintendent of the Postgraduate School is a rear admiral of the line of the Navy. His principal assistants are an Academic Dean who is the senior member of the civilian faculty and two captains of the line, the Deputy Superintendent for Operations and Programs, and the Deputy Superintendent for Administration and Logistics.

The academic programs and direct supporting functions are administered and operated through a unique organization composed of Curricular Offices and Academic Depart-



ments. The former are staffed by naval officers whose primary functions are threefold: (1) academic and military supervision and direction of officer students; (2) coordinating, in conjunction with Academic Associates, the elements of each curriculum within their program areas; and (3) conducting liaison with curricula sponsor representatives. Officer students are grouped into the following curricular programs areas:

- Aeronautical Engineering
- Electronics and Communications Engineering
- Ordnance Engineering
- Naval Engineering
- Environmental Sciences
- Naval Management and Operations Analysis
- Engineering Science
- Baccalaureate

Officer students in each curricula group pursue similar or closely related curricula. With most of these areas a common core program of study is followed for at least half the period of residency.

Objectives and details of curricula are contained elsewhere in this catalogue.

The teaching functions of classroom and laboratory instruction and thesis supervision are accomplished by a faculty which is organized into ten academic departments:

- Aeronautics
- Business Administration and Economics
- Electrical Engineering
- Government and Humanities
- Material Science and Chemistry
- Mathematics
- Mechanical Engineering
- Meteorology and Oceanography
- Operations Analysis
- Physics

Over three-fourths of the teaching staff are civilians of varying professorial rank and the remainder naval officers.

Detailed listings of faculty members and course offerings are contained in later sections of the catalogue.

The Academic Program organization described is supervised by the Deputy Superintendent for Operations and Programs and a civilian Dean of Programs who collaborate to share jointly the responsibilities for planning, conduct and administration of the several educational programs. An Executive Assistant to the Deputy Superintendent for Operations and Programs, similarly shares curricular responsibilities with a Dean of Curricula in a position just above the Curricular Officers.

The close tie between elements of this dual organization is further typified by the Academic Associates. These are individual civilian faculty members appointed by the Academic Dean to work closely with the Curricular Officers in the development and continuing monitoring of curricula—the Navy's needs being the responsibility of the Curricular Officer and academic soundness being the responsibility of the Academic Associate.

The educational programs conducted at Monterey fall into several general categories:

- a. Engineering and scientific education leading to designated baccalaureate and/or advanced degrees.
- b. Management education to the Master's level.
- c. Undergraduate education leading to a first baccalaureate degree, either B.S. or B.A.

Supplementing category a. above is the Engineering Science program. The major portion of the officers selected for this program undergo two terms of refresher and prerequisite study. Those who are so motivated and available for the requisite time may be selected by the Superintendent for a two or three year engineering or science curriculum. Those not selected continue in a non-degree program with the primary objective of basic scientific education which will better prepare them for advanced functional training and/or general updating in technical areas.

Logistic service support is rendered by conventional departments such as Supply and Disbursing, Public Works, Dental, Public Affairs and Visit Liaison, etc., grouped organizationally under a Deputy Superintendent for Administration and Logistics. Certain other offices such as that of the Comptroller are directly responsible to the Superintendent in a slightly modified but typical naval staff organization.

## FACILITIES

The School is located about one mile east of downtown Monterey on the site of the former Del Monte Hotel. Modern classroom and laboratory buildings have been constructed and are situated on a beautifully landscaped campus.

The Superintendent and central administrative officers are located in the main building of the former hotel, now called Herrmann Hall. The East wing of the main building complex has been converted into classroom and administrative spaces and a portion of the ground floor of the West wing has been similarly converted.

Spanagel, Bullard, Halligan, and Root Halls are modern buildings which are devoted to classroom, laboratory and faculty office spaces. About one-third of Root Hall houses the Library and Reference Center. A fifth new building of matching architectural style is King Hall—the main auditorium.

Additional smaller buildings about the campus house specialized laboratory facilities as well as various support activities. A group of buildings comprising new Aeronautical Propulsion Laboratories has recently been completed.

## STUDENT AND DEPENDENT INFORMATION

Monterey Peninsula and the cities of Monterey, Carmel, Pacific Grove, and Seaside, all within 5 miles of the School, provide community support for the officers of the Postgraduate School.

La Mesa Village, located 3 miles from the School, consisting of former Wherry Housing and new Capehart Housing, contains 768 units of public quarters for naval personnel.

An additional 118 units are presently under construction. An elementary school is located within the housing area.

The Naval Auxiliary Landing Field is located about one mile from the School. Aircraft are available for maintaining flight proficiency. Cross-country flights up to 1200 miles are now permitted. One half-day each week is scheduled for flying as part of the aviator student's work-week.

On the main School grounds are 149 BOQ rooms, an Open Mess, a Navy Exchange, 4 tennis courts, a large swimming pool and 6 lane bowling alley. An eighteen-tee nine-hole Navy golf course is located near the main campus.

Medical facilities include a Dispensary at the Naval Auxiliary Landing Field, Monterey, supported by the U.S. Army Hospital, Fort Ord (7 miles away) and the U.S. Navy Hospital at Oakland (120 miles away). A Dental Clinic is located in Herrmann Hall.

### ADMISSIONS PROCEDURES

U.S. Navy officers interested in admission to one of the curricula offered at the Postgraduate School are referred to BuPers Notice 1520, Subject: Postgraduate and Undergraduate Education Programs, which is published annually by the Chief of Naval Personnel. This directive outlines the various educational programs available and indicates the method of submitting requests for consideration for each program.

A selection board is convened annually by the Chief of Naval Personnel to select officers, based upon professional performance, academic background, and ability, within quotas which reflect the Navy's requirements in the various fields of study available. Officers will be notified of selection by a BuPers Notice at the earliest feasible date after the meeting of the selection board, or by official correspondence.

The curriculum numbers as assigned in the annual BuPers Notice 1520 are repeated in the title of each curriculum and are also included in the list of curricula at the Postgraduate School on page 25 and the list of curricula conducted at civilian institutions on page 61.

Officers on duty with other branches of service are eligible to attend the Postgraduate School. They should apply in accordance with the directives promulgated by the Department of the Army, Department of the Air Force, Commandant U.S. Marine Corps, or the Commandant U.S. Coast Guard, as appropriate.

Military officers from Allied Countries may be admitted to certain curricula at the Postgraduate School. Such admission is subject to availability of quotas assigned to each country. Applications must be made through normal channels of communication and not sent directly to the Naval Postgraduate School. The academic standards described in this Catalogue for admission to each curricula must be met.

Civilian students are not eligible to attend the Postgraduate School.

### DEGREES, ACCREDITATIONS, AND ACADEMIC STANDARDS

The Superintendent is authorized to confer Bachelor's, Master's or Doctor's degrees in engineering or related fields upon qualified graduates of the School. This authority is

subject to such regulations as the Secretary of the Navy may prescribe, contingent upon due accreditation from time to time by the appropriate professional authority of the applicable curricula. Recipients of such degrees must be found qualified by the Academic Council in accordance with prescribed academic standards.

The Naval Postgraduate School was accredited in 1962 as a full member of the Western Association of Schools and Colleges. Initial accreditation as an associate member was given in 1955. Specific engineering curricula have been accredited by the Engineers' Council for Professional Development (ECPD) since 1949.

Beginning with the 1967-68 academic year, the Postgraduate School will operate on a 12-week quarter calendar, with the last week of each quarter set aside for final examinations. Prior to this year, the academic schedule was based on 10-week terms.

Students' performance is evaluated on the basis of a quality point number assigned to the letter grade achieved in a course as follows:

<i>Performance</i>	<i>Grade</i>	<i>Quality Point Number</i>
Excellent	A	3.0
Good	B	2.0
Fair	C	1.0
Barely Passing	D	0.0
Failure	X	-1.0

When the quarter hours value of a course is multiplied by the quality point number of the student's grade, a quality point value for the student's work in that course is obtained. The sum of the quality points for all courses divided by the sum of the quarter hour value of all courses gives a weighted numerical evaluation of the student's performance termed the Quality Point Rating (QPR). A student achieving a QPR of 2.0 has maintained a B average in all courses undertaken with a proper weight assigned for course hours. Satisfactory academic proficiency at the Naval Postgraduate School has been established at a QPR of 1.0 for all courses of a curriculum.

Officer students have no major duties beyond applying themselves diligently to their studies. It is expected that students will maintain a high level of scholarship and develop attributes which are associated with a scholar seeking knowledge and understanding. Program schedules are such that the student should anticipate spending several hours in evening study each weekday to supplement time available for this purpose between classes.

The courses listed in this Catalogue are assigned a level of academic credit by the numbers assigned.

0001 - 0999	No credit
1000 - 1999	Lower division credit
2000 - 2999	Upper division credit
3000 - 3999	Upper division or graduate credit
4000 - 4999	Graduate credit

The two numbers in parenthesis (separated by hyphens) following the course title indicate the hours of instruction per week in classroom and laboratory respectively. Laboratory hours are assigned half the value shown in calculating quarter hours for the credit value of the course. Thus a



(3-2) course (having three hours recitation and two hours laboratory) will be assigned a credit value of 4 quarter hours.

## ACADEMIC HONORS

**PROFESSIONAL SOCIETIES.** Students have the opportunity to attend many professional meetings held at the Naval Postgraduate School. Several local chapters provide for student membership. These include the American Meteorological Society, Association for Computing Machinery, American Society of Mechanical Engineers, The Institute of Electrical and Electronics Engineers, Inc.

**DEAN'S LIST.** Students who distinguish themselves academically are recognized at the end of each quarter by being placed on the Dean's List. This recognition is awarded to students who earn a Quality Point Rating of 2.65, or higher, while carrying a minimum academic load of 12 quarter hours.

**GRADUATION WITH DISTINCTION.** This recognition may be awarded to students earning either a Bachelor's Degree or a Master of Science Degree. To be eligible a student must have completed in residence a minimum of 108 quarter hours toward a Bachelor's degree, and 60 quarter hours toward a Master of Science degree. This recognition is awarded to students who earn a Quality Point Rating of 2.75, or higher.

**SIGMA XI.** The Naval Postgraduate School has a Chapter of the Society of the Sigma Xi, an honorary society founded to recognize excellence in the scientific and engineering disciplines. Students who have demonstrated marked promise in their research work are considered for membership each year. The number elected is limited only by the quality of the research work done for a graduate degree.

**MEWBORN STUDENT RESEARCH AWARD.** This award affords recognition for exceptional research talent. It is awarded annually to a student in a program of graduate scientific or engineering studies, leading to an advanced degree, whose thesis exhibits sound scholarship and outstanding research ability.

**CAPTAIN J. C. WOELFEL AWARD.** This award is given annually to the United States Naval officer student receiving an advanced degree in the Naval Engineering Programs who has demonstrated the most outstanding academic record, and at the same time possesses those attributes best exemplifying a Naval Officer.

## DIPLOMAS OF COMPLETION

Diplomas of Completion are issued to students completing programs which do not offer a degree. To establish eligibility for a Diploma of Completion, a student must obtain an over-all QPR of 1.0 or better. Where applicable, students obtaining a QPR of 2.75 or better will receive Diplomas of Completion "With Distinction."

## REQUIREMENTS FOR THE BACCALAUREATE DEGREE

1. The Bachelor of Science or the Bachelor of Arts Degree may be awarded for successful completion of a curriculum which has been approved by the Academic Council as meriting the degree. Such curricula shall conform to current practice in other accredited institutions and shall contain a well-defined major.

2. General Postgraduate School minimum requirements for the Baccalaureate Degree are as follows:

- a. 180 quarter hours of which at least 72 hours must be at the upper division level from courses numbered at or above 2000.
- b. One academic year in residence.
- c. 36 quarter hours in the Humanities and the Social Sciences.
- d. 36 quarter hours in Mathematics and the Physical Sciences.
- e. Completion of the departmental requirements for a well-defined major.
- f. A quality point rating of at least 1.00 in all courses taken at the Postgraduate School, as well as in the courses in the major.

## REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

1. The Master's Degree may be awarded for successful completion of a curriculum which has the approval of the Academic Council as meriting the degree. Such curricula shall conform to current practice in accredited institutions and shall contain a well defined major.

2. General Postgraduate School minimum requirements for the Master of Science Degree are as follows:

- a. 40 quarter hours of graduate level courses.
- b. A thesis or its equivalent is required.
- c. One academic year in residence.
- d. Departmental requirements for the degree in a specified subject.

3. Admission to a program leading to the Master of Science degree requires a baccalaureate degree with appropriate undergraduate preparation for the curriculum to be pursued. If a student enters the Postgraduate School with inadequate undergraduate preparation, he will be required to complete the undergraduate prerequisites in addition to the degree requirements.

4. In order to qualify for a Master's Degree, a student first must be admitted to candidacy for the degree. Application for admission to candidacy must be made subsequent to completion of 50% of his curriculum, and prior to completion of 75% of the curriculum. Students having a quality point rating of 2.00 or greater in all courses of their curricula are qualified for admission to candidacy. Students having a total quality point rating from 1.50 to 1.99, inclusive, may be admitted to candidacy by the Academic Council upon recommendation of the Chairman of the Department of the major. Students with a total quality point rating below 1.50 will be ineligible for admission to candidacy.

5. To be eligible for the Master's Degree, the student must attain a minimum average quality point rating of 2.00 in all the graduate level courses in his curriculum and

either 1.50 in the remaining courses or 1.75 in all courses of the curriculum. In very exceptional cases, small deficiencies from these grade averages may be waived at the discretion of the Academic Council.

### REQUIREMENTS FOR THE DOCTOR'S DEGREE

1. The Doctor's Degree (in engineering and related fields) is awarded as a result of very meritorious and scholarly achievement in a particular field of study which has been approved by the Academic Council as within the purview of the Naval Postgraduate School. A candidate must exhibit faithful and scholarly application to all prescribed courses of study, achieve a high level of scientific advancement and establish his ability for original investigation. He shall further meet the requirements described in the following paragraphs.

2. Any program leading to the Doctor's Degree shall require the equivalent of at least three academic years of study beyond the undergraduate level with at least one academic year being spent at the Naval Postgraduate School.

3. A student seeking to become a candidate for the Doctorate shall hold a Bachelor's degree from a college or university, based on a curriculum that included the prerequisites for full graduate status in the department of his major study, or he shall have pursued successfully an equivalent course of study. The student shall submit his previous record to the Chairman of the Department of his proposed major subject for determination of his acceptability as a Doctoral student.

4. This chairman will consult with two or more selected department chairmen to nominate a doctoral committee for the student. The committee will consist of five or more members with at least one representative from each of the selected departments. The Department Chairman of the student's major will submit the proposed committee names to the Academic Council for its approval.

5. The Doctoral Committee has full responsibility for prescribing a program of study, which shall include one or more minor fields, suitable to the needs of the student and the requirements for award of the Doctorate.

6. When the program of study in his major and minor field is essentially complete, the student shall be given qualifying examinations, including those associated with the foreign language requirement. The qualifying examinations in the major and minor fields will be both written and oral and will be conducted by the Doctoral Committee. The

members of the Academic Council or their delegates will be invited to attend the oral examinations.

7. The foreign language requirement is to be satisfied by the student demonstrating before an examiner appointed by the Academic Dean that he possesses a satisfactory ability to read work related to his special field of study in at least two foreign languages. The accepted languages are French, German and Russian. If the student can demonstrate that enough current technical literature in his major field exists in another foreign language, the Doctoral Committee may substitute this for one of the accepted languages. Preparations for meeting this requirement should begin early in the student's program.

8. Upon successful completion of the qualifying examinations, and the fulfillment of the foreign language requirements, the student becomes a candidate for the Doctorate. The Doctoral Committee will report to the Academic Council the student's advancement to candidacy. After advancement, the candidate must devote at least six months to research before he may expect to present himself for the final examination. All requirements must be satisfied within a maximum period of five years after advancement to candidacy.

9. The distinct requirement of the Doctorate is a successful completion of a scholarly investigation leading to an original and significant contribution to knowledge in the candidate's major area of study. The subject of the investigation must be approved in advance, by the Doctoral Committee. When the results of the investigation are completed, a copy of the dissertation shall be submitted to each member of the Doctoral Committee. The Committee will make the final decision on the acceptance of the dissertation.

10. After the approval of the dissertation, and not later than two weeks prior to the award of the degree, the Committee will conduct a final oral examination of the candidate. The members of the Academic Council or their delegates will be invited to attend the examination. In this final examination, the candidate will be asked to defend his Dissertation and in addition shall be questioned on any subject deemed important to the Committee. Upon completion of the final examination the Committee will nominate the successful candidate to the Academic Council for the award of the Doctor's degree. The Committee will supply to the Council such information concerning the candidate as may be requested by the Council Secretary.

11. With due regard for all the requirements for awarding the Doctorate and the recommendations of the Doctoral Committee, the Academic Council will make the final decision to recommend the candidate to the Superintendent of the Naval Postgraduate School for the award of the degree.

### SUPERINTENDENT'S GUEST LECTURE PROGRAM

During the third and fourth quarters a weekly series of lectures will be presented on Wednesday afternoons in King Hall for students, faculty and staff. Eminently qualified civilian and military authorities from a wide range of fields and accomplishments will speak on subjects of current and historical interest in international, governmental, sociological, and military affairs. The primary purpose of this series is to inform as well as to stimulate and challenge the thinking of the officer students in areas outside of their immediate academic pursuits.

## THE COMPUTER FACILITIES

## STAFF

DOUGLAS GEORGE WILLIAMS, Professor and Head (1961);  
M.A. (Honours), Univ. of Edinburgh, 1954.

*Applications Programming Division*

ROGER RENE HILLEARY, Mathematician and Supervisor  
(1962); B.A., Pomona College, 1953.

RONALD DAVID BRUNELL, Mathematician (1965); B.A., San  
Fernando Valley State College, 1961.

LOIS MAY BRUNNER, Programmer (1961); A.A., Monterey  
Peninsula College, 1963.

SHARON DILL RANEY, Mathematician (1964); B.S., Califor-  
nia State Polytechnic, 1964.

ROBERT STEPHEN WALTON, Mathematician (1961); B.S.,  
Massachusetts Institute of Technology, 1949.

*Systems Programming Division*

EDWARD NORTON WARD, Mathematician and Supervisor  
(1962); B.A., Univ. of California at Los Angeles, 1952.

SALLY VIRGINIA KLINE, Mathematician (1965); B.S.,  
B.S.Ch.E., West Virginia Univ., 1960.

ERNEST GEOFFREY JANZEN, Mathematician (1963); B.S.,  
Univ. of Southern Mississippi, 1962.

*Processing Division*

MAXWELL JOSEPH FEURMAN, Supervisor (1961).

## DESCRIPTION

The Naval Postgraduate School was one of the first institutions in this Country to introduce digital computers into their academic programs. The first computer, a NCR 102A, was delivered in 1954. In 1960 the Computer Facility moved to its present location in Spanagel Hall.

During the period from 1960 to 1967, the School acquired and operated on a three-shift basis, four computers: A CDC

1604 (Serial #1) with 32K core and 8 tape units; a CDC 160 with tape and an IBM 1401 with disc and tapes, both machines operating primarily in support of the CDC 1604. The CDC 160 (and a similar system in the Digital Control Laboratory, Department of Electrical Engineering) were connected to the 1604 for multi-processing operation. Programming languages available included FORTRAN, COBOL, ALGOL and assembly language.

In 1967 the CDC 1604 was replaced by a large-scale computer system based on the IBM 360 Model 67. The configuration consists of two connected central processing units accessing a combination of core, drum, disc and tape storage. The input-output devices include, in addition to the standard peripheral equipment, a variety of remote terminals distributed on campus. The ultimate goal is to provide a computational utility which is responsive simultaneously to the demands of a wide variety of uses; e.g., students programming in a conversational mode at remote typewriters, operations personnel running an orthodox batch-processing service in the central facility, and research workers in laboratories with a requirement for real-time data reduction and control. Programming systems include FORTRAN, COBOL, ALGOL, assembly language, and simulation languages.

The Computer Facility's primary function is to support the academic programs, serving as a laboratory adjunct to courses on computer programming, logical design and the use of computers in solving scientific engineering and management problems as well as those of interest specifically to the Navy.

The facility has a staff of programmer-mathematicians who provide a consulting service to students and faculty in programming and problem formulation. In addition, efforts are concentrated toward developing and maintaining a library of programs and subroutines, improving programming systems, and generally creating a suitable environment for class and research use of computers.

Current Facility activity includes work in the areas of scientific, engineering and management computing, systems programming, information retrieval, administrative information systems, and graphical data processing.



*Visitors viewing Computer equipment*





*Current Postgraduate Facility*



*Artist's concept of completed Postgraduate Facility*

## THE LIBRARIES

## STAFF

GEORGE RIDGLEY LUCKETT, Professor and Librarian (1950); B.S., Johns Hopkins Univ., 1949; M.S., Catholic Univ., 1951.

PAUL SPINKS, Associate Professor and Associate Librarian (1959); B.A., Univ. of Oklahoma, 1958; M.S., 1959.

EDGAR RAYMOND LARSON, Assistant Professor and Reader Services Librarian (1959); B.A., Univ. of Washington, 1939; B.S., 1950.

JANUSZ I. KODREBSKI, Assistant Professor and Head Cataloger (1956); Officer's Diploma, National War College, Warsaw, Poland, 1938; M.S., Univ. of Southern California, 1955.

JANUSZ TYSKZIEWICZ-LACKI, Assistant Professor and Technical Reports Librarian (1961); Absolutorium, Univ. of Poznan, Poland, 1924; M.S., Univ. of California at Berkeley, 1958.

GEORGIA PLUMMER LYKE, Reference Librarian (1952); A.A., Hartnell College, 1940.

MABEL CHARLOTTE VAN VORHIS, Librarian, Physical Sciences and Engineering (1955); B.A., Univ. of California at Berkeley, 1926.

ROBERT MORAN TIERNEY, Acquisitions Librarian (1957); B.A., Columbia Univ., 1937; M.A., San Jose State College, 1962.

ALICE MARIE STUDE, Cataloger (1957); B.S., Univ. of Minnesota, 1930; M.S., Univ. of California at Berkeley, 1961.

ELSA MARIA KUSWALT, Cataloger (1958); B.A., Univ. of California at Berkeley, 1957; M.L.S., Univ. of Southern California, 1966.

DORIS McNUTT BARON, Librarian, Physical Sciences and Engineering (1961); B.A., Univ. of California at Berkeley, 1946; M.S., Univ. of Southern California, 1960.

MARY THERESE BRITT, Librarian (1966); B.S., College of St. Catherine, 1947.

CLEO ELIZABETH PETERSON, Cataloger (1958); A.A., Red Oak College, 1938.

MARY TOBY KUHN, Librarian (1966); B.A., Mills College, 1963; M.L.S., Univ. of California at Berkeley, 1964.

## DESCRIPTION

The Library system serves the research and instructional needs of the community comprising students, faculty, and staff of all departments of the School. It embraces an active collection of 120,000 books, 188,000 technical documents, over 2400 periodical works currently received, and 140,000 abstract cards and microcards. These materials parallel the School's curricular fields of engineering, physical sciences, industrial engineering, management, naval sciences, government and the humanities.

The Reference Library, located at the southeast end of Root Hall, provides the open literature sources such as books, periodicals and journals, indexes and abstracting services, pamphlet materials and newspapers. It also furnishes facilities for microfilming and microfilm reading, for photographic and contact reproduction of printed matter, and for borrowing, from other libraries, publications not held in its collections.

The Technical Reports and Classified Materials Section is the principal repository for technical research documents received by the School. It houses 180,000 documents, 65,000 of which are classified, and exercises control over the micro-card collection. A machine information storage and retrieval system that utilizes the School's computer facilities is available for literature searches of documents received since November, 1960. An SDI (Selective Dissemination of Information) service, designed to broaden the scope of the Library's automated services to the Postgraduate School, was initiated in January, 1967.

The Christopher Buckley, Jr., Library is a branch of the Reference Library and is located on the first floor adjacent to the lobby. It is a collection of some 8,000 volumes pertaining principally to naval history and the sea. The establishment of this collection was made possible by the interest and generosity of Mr. Christopher Buckley, Pebble Beach, California, who began donating books to the School for this Library in 1949.



*Reference Library*



## LABORATORY FACILITIES

Extensive laboratory experimentation is carried on in connection with the instructional and research programs of the School. Experimental facilities have been greatly improved and expanded in recent years. Further expansion and improvement is planned for the future in response to emerging requirements.

The AERONAUTICAL LABORATORIES contain facilities for experimentation and research in aerodynamics, structural and stress analysis, aerothermodynamics, rocket and jet propulsion, and turbomachinery.

The Subsonic Aerodynamics Laboratory consists of two subsonic wind tunnels, one with a 32x45 inch test section and a speed range up to 185 knots, and the other with a 42x60 inch test section and a speed range up to 200 knots. Force and moment beam balances measure aerodynamic reactions. A small classroom wind tunnel, 7x10 inches in cross-section, and a small two-dimensional smoke tunnel are also in use. Equipment for operating powered propeller aircraft models is available. Experiments in boundary layers, pressure distribution, component aerodynamics, performance and dynamics can be performed.

The Structural Test Laboratory contains testing machines with varying capacities up to 600,000 pounds for demonstration and analysis of relatively small structures. Large aircraft components such as a P2V wing, a F8U-3 wing, and an A3D tail are accommodated on the loading floor of the laboratory where static vibration tests are carried out.

The Dynamics Test Laboratory uses a 20 amplifier analog computer, two electromagnetic shakers, and associated electronic instrumentation for demonstrations of the principles of structural dynamics.

The facilities of the Compressibility Laboratory include a transonic wind tunnel having a 4"x16" test section and operating in the Mach number range from 0.4 to 1.4; a supersonic wind tunnel having a 4"x4" test section and a vertical free-jet of 1"x1" cross-section, both operating in the Mach number range from 1.4 to 4; and a 4"x16" shock tube. Instruments associated with these facilities include a 9" and 6" Mach-Zehnder interferometers and 9" and 5" Schlieren systems for flow observations.

The Rocket and Jet Engine Laboratory facilities provide for full scale operation of current and future Naval aircraft jet engines, and for small rocket engines of 2,000 pounds thrust or less. Two separate and complete test cells are provided in one building for the operations of a J57 engine with afterburner and for the future installation of a T56 turboprop engine. A separate engine maintenance shop is located adjacent to these test cells. A separately located external pad and control house are presently in use for the operation of a J34 jet engine and a Boeing XT-50 turboprop engine. Rocket engine tests can be run from a common control room in three test cells housed in the rocket engine building, which also contains a propellant chemistry laboratory. The three test cells provide for operation of solid rocket engines, liquid rocket engines, and hybrid or experimental engines.

The advanced facilities of the Cascade and Turbomachinery Laboratories are distributed in three buildings, one of which provides low speed tests with rectilinear, cylindrical and rotating cascades of large dimensions. The source of air is a 700 HP fan, either to draw or to blow air through the test items, which delivers about 100,000 cfm of air at a pressure difference of about 40 inches of water. This source can be used also to perform model tests with flow channels, inlet and discharge casings, scrolls and diffusers. The special rectilinear cascade test rig is equipped with semi-automatic instrumentation; data are obtained with an electronic logging system for data reduction on digital computers. A second building houses a centrifugal compressor test rig, instrumented for conventional performance measurements and for special investigations of three-dimensional flows about both the stationary and the rotating vanes. The third building is devoted to high speed tests, in three tests cells, monitored from a central control room. A 1250 HP variable-speed axial-flow compressor, which is instrumented also for interstage measurements, produces high pressure air either for turbine testing, or to drive test compressors, pumps, and other test items. The compressor is capable of delivering 10,000 cfm of air at sea-level conditions. The design pressure ratio is three, and speed control is possible between 40% and 100% of design speed by means of a hydraulic drive. A surge-suppressing device makes it possible to operate test items with greatly varying flow rates. Data acquisition is carried out with an electronic logging system as well as with conventional instrumentation. Adjacent to the third building is a hotspin test unit, where disks and propellers can be rotated at speeds up to 50,000 rpm. Heating and cooling elements make it possible to impose radial temperature gradients. Instrumentation is provided to conduct stress work, with strain gauges, up to 27,000 rpm and at maximum temperatures of 1800°F.

The CHEMICAL LABORATORIES provide facilities for undergraduate and graduate study and research in chemistry and chemical engineering. Included for these purposes are: a radio-chemistry ("hot") laboratory with Geiger and scintillation counters and special apparatus for handling and testing radio-active materials; a molecular spectroscopy laboratory, including high resolution infra-red and ultraviolet spectrophotometers, an electron paramagnetic resonance spectrometer, and associated high vacuum manifolds; a chemical instruments laboratory for instruction in the use and theory behind obtaining data with infrared and ultraviolet spectrophotometers, vapor refractometers, refractometers, vapor pressure osmometers, polarographs, and other instruments commonly used for chemical determinations. A plastics laboratory is available where plastics are synthesized, molded in compression or injection presses, and their mechanical, physical, and chemical properties are determined. The department has a well-equipped fuel and lubricant laboratory, and an explosives laboratory with impact tester, ballistics mortar, chronograph and other apparatus for evaluating explosives. In the rocket propellant laboratory, small batches of solid propellents can be produced and many of the ballistic parameters and mechanical

properties measured. Facilities are available for burning rate studies. Thrust stands in the adjoining facility provide for static firing of solid and liquid propellant motors.

The ELECTRICAL ENGINEERING LABORATORIES have ample facilities for comprehensive instructional and research programs in all phases of present-day electrical engineering, including electrical circuits, machinery and measurements, electronic devices, circuits and systems, feedback control mechanisms and systems, and computer technology.

The extensive conventional facilities in the Electrical Circuits and Machinery Laboratories are supplemented by special bridges and other measuring equipment, data-recording devices and generalized machine sets. Analog computers are available for simulation and analysis of circuits and machines.

In the Electronics Laboratories, facilities are provided for investigating the characteristics of modern electronic devices, circuits and equipments at frequencies ranging from d-c to the optical region. Available systems include representative communications, radar, telemetry, sonar and countermeasures systems, and navigational aids. Special facilities are available for intensive study of transmission and radiation properties of electromagnetic energy, including a microwave anechoic chamber and an antenna model range.

The Digital Control Laboratory provides special computational facilities, including a satellite digital processor, a hybrid linkage system and versatile computer accessing displays. These facilities support studies in signal processing, digital communications, surveillance and tracking, control theory, computer programming, time-sharing systems, tactical simulation and war gaming.

The Servomechanisms Laboratory is equipped with analyzers, recorders and the basic units required to synthesize and test a wide variety of systems. Analog computers serve an important role in the synthesis and analysis of control systems.

A Standards and Calibration Laboratory is used for precision measurements and to calibrate the laboratory instruments. Excellent standard frequency sources and standardizing equipment are available.

The MATERIALS LABORATORIES are well equipped for both materials science and materials engineering studies and research. For these purposes standard universal testing machines, hardness testers, etc. are available for mechanical property determinations. For metallurgical studies the laboratory is equipped with heat-treating furnaces, metallographs, and microscopes. A plastics laboratory is available for evaluation of the mechanical, physical and chemical properties of plastics. Facilities for basic materials science studies include: several x-ray diffraction units; precision heating and powder cameras; Weissenberg x-ray unit; precision goniometers; recording photo-densitometer, etc. Metal fabricating equipment includes welding facilities, a swaging machine, rolling mill, induction and vacuum melting furnaces and a die-casting machine, and provides facilities for materials processing studies. A laboratory for high and low temperature studies of materials, including creep test-

ing machines, afford additional modern equipment for materials research.

Laboratory equipment for MATHEMATICS now available includes an electronic and analogue computer and a digital differential analyzer both of which are used to find the solutions of differential equations; a specially modified accounting machine used in finite differences computations, a variety of planimeter type instruments including a large precision moment integrator, a Stieltjes integrator and a harmonic analyzer. A large number of modern electric desk calculators are available in the laboratory for numerical methods and statistics. Many special models and demonstrators, including the only two automatic relay controlled Wald Sequential Sampling Machines ever made, and other devices and visual aids in mathematics, probability and mechanics are used in support of courses in these subjects. An 85 foot Foucault Pendulum with an 184 lb. bob is kept in constant operation and display.

The MECHANICAL ENGINEERING LABORATORIES provide facilities for instruction and research in heat-power, heat transfer, fluids mechanics, deformable body mechanics, and dynamics. Noteworthy equipment in the heat-power laboratories includes a gas fired boiler, 200 psi, and 8000 lb/hr, full automatic controls; a 175 HP gas turbine installation, dynamometer loaded; a two dimensional supersonic air nozzle with Schlieren equipment for analysis of shock-wave flows; a two-stage axial flow test compressor; an experimental single cylinder diesel engine; a multistage centrifugal blower; an air flow metering bench; hydraulic test equipment including a two-stage centrifugal pump, a deep well pump, an impulse turbine and a torque converter, a single-blow transient testing facility for compact heat exchanger surfaces; a steam to air facility for testing heat exchangers; and a small cryogenic facility for evaluating cryopumping surfaces.

Facilities in the mechanics laboratory include equipment for static, fatigue, and impact testing. Stress analysis equipment includes instrumentation for multi-channel recording of static and dynamic strains, a photoelastic laboratory, and facilities for brittle lacquer studies. Dynamics equipment includes electrodynamic exciters, force and motion transducers and associated instrumentation. An analog computer laboratory provides for electronic simulations of linear and nonlinear engineering systems.

METEOROLOGY AND OCEANOGRAPHY FACILITIES include all instruments in present-day use for measuring the physical and dynamic state of the atmosphere, as well as teletype and facsimile communications equipment for the rapid reception and dissemination of weather data in coded and analyzed form for the entire northern hemisphere.

The instruments for gathering weather data include rawinsonde equipment, which provides a continuous recording of temperature, pressure, humidity and wind direction and velocities at designated levels above the surface; radiosonde equipment whereby pressure, temperature and humidity information is transmitted to ground via radio signals from heights that may extend above 100,000 feet; a wire-sonde that measures air temperature and humidity condi-



tions in the lower strata of the atmosphere, and inversion meter designed for remote recordings of free air temperature at designated heights in the boundary layer.

The school has recently installed an automatic picture transmission (APT) receiving apparatus for the reception of pictures from the NIMBUS and TOS weather satellites. Rectification grid templates are used in the laboratories for direct correlation of current satellite pictures with conventional synoptic analyses and nephanalyses.

The proximity of the Fleet Numerical Weather Facility on the school grounds provides introduction to the latest environmental computer products and the high speed data links utilized to provide transmission and automatic reproduction through a world-wide network.

The school operates a 63-foot boat converted for use in oceanographic instruction and research. It is utilized for actual field oceanographic studies by Environmental Sciences students. Included in its installed equipment are deep and shallow echo sounders, a bathythermograph winch, and a deep sea hydrographic winch using 20,000 feet of wire.

Oceanographic equipment installed in the area near the school include a wave gauge and a tide gauge for recording nearshore wave action and local tide fluctuations.

Joint development by the school and the Naval Special Device Center of a wave and current generator have progressed to the point of the installation of the prototype on campus.

The PHYSICS LABORATORIES are equipped to carry on instructional and research work in nuclear physics, low temperature and solid state physics, plasma physics, spectroscopy, and acoustics.

The laboratory facilities include a nuclear physics laboratory centering around a two million volt Van de Graaff accelerator, an Aerojet Nucleonics nuclear reactor operating at power levels up to 1000 watts, and an electron linear accelerator with a maximum energy of 100 million electron volts, and 20 micro ampere beam intensity.

In low temperature and solid state physics the equipment includes nitrogen liquefiers, a Collins helium liquefier, He<sup>3</sup> refrigeration equipment to reach temperatures below 1° K, a 12 inch uniform field electromagnet, microwave gear for spin resonance and maser studies, and high frequency pulse acoustic equipment for phonon studies.

The plasma physics equipment includes a number of small vacuum systems, a large plasma system, and diagnostic equipment for studies of plasma dynamics. A steady state plasma source with magnetic fields up to 10,000 gauss will soon be available for plasma research. The spectroscopy equipment includes a large grating spectrograph, a large prism spectrograph, and an infrared spectrophotometer.

The acoustics laboratory equipment includes a large anechoic chamber, a small reverberation chamber, and a multiple-unit acoustics laboratory for students experimentation in airborne acoustics. Sonar equipment, test tanks, and instrumentation for investigation in underwater sound comprise the sonar laboratory.

The REACTOR LABORATORY features an AGN-201 reactor which has been modified to operate at powers up to 1000 watts. The Laboratory provides facilities and equipment for teaching and research in nuclear physics, radiochemistry, and reactor physics.

A 120 MeV LINEAR ACCELERATOR was officially placed into service at the school in February, 1966.

The new accelerator is a valuable tool in the intermediate energy range. It is being used to investigate the physics of nuclear structure, as distinct from the physics of elementary particles.

The accelerator has a continuous energy range from 5 to 120 MeV with a maximum beam current of 20 microamps. Each of three 10 foot section is powered by a 21 megawatt klystron. Present experiments include inelastic electron scattering from nuclei.

The accelerator is also used for radiation damage studies on solid state electronics devices.

*CURRICULAR OFFICES*  
*and*  
*PROGRAMS*





*The Main Administration Building, Herrmann Hall*

## CURRICULA AT THE POSTGRADUATE SCHOOL

<i>Curriculum</i>	<i>Curriculum Number</i>	<i>Length</i>	<i>Convening Dates</i>
Advanced Science			
Chemistry .....	380	33 mo.	March, September
Hydrodynamics .....	380	33 mo.	March, September
Mathematics (Applied) .....	380	33 mo.	March, September
Material Science .....	380	33 mo.	March, September
Physics (General) .....	380	33 mo.	March, September
Physics (Nuclear) .....	380	33 mo.	March, September
Aeronautical Engineering			
General .....	610	21 mo.	March, September
Advanced .....	610	33 mo.	March, September
Baccalaureate			
Bachelor of Science .....	461	24 mo.	January, July
Bachelor of Arts .....	461	24 mo.	January, July
Electronics and Communications Engineering			
Communications Engineering			
Basic .....	600	21 mo.	March, September
Advanced .....	600	33 mo.	March, September
Engineering Electronics			
Basic .....	590	21 mo.	March, September
Advanced .....	590	33 mo.	March, September
Information and Control .....	590	33 mo.	March, September
Special (CEC) .....	472	12-18 mo.	September
Staff Communications .....	620	9 mo.	March, September
Engineering Science .....	460	9 mo.	March, September
Environmental Sciences			
Advanced Meteorology .....	372	21 mo.	March, September
General Meteorology .....	372	21 mo.	March, September
Oceanography .....	440	21 mo.	March, September
Naval Engineering			
Mathematics .....	430	9 mo.	July
Naval Engineering (Mechanical) .....	570	21 mo.	March, September
Naval Engineering (Electrical) .....	570	21 mo.	March, September
Mechanical Engineering (Advanced) .....	570	33 mo.	March, September
Electrical Engineering (Advanced) .....	570	33 mo.	March, September
Naval Management and Operations Analysis			
Computer Science .....	368	21 mo.	March, September
Management Data Processing .....	367	15 mo.	September
Management .....	817	12 mo.	January, July
Operations Research/Systems Analysis .....	360	24 mo.	March, September
Ordnance Engineering			
Nuclear Engineering (Effects) .....	521	24 mo.	July
Underwater Physics Systems			
Basic .....	535	21 mo.	September
Advanced .....	535	33 mo.	September
Ordnance Systems Engineering			
General .....	530	21 mo.	March, September
Special .....	530	21 mo.	March, September
Advanced			
Air/Space Physics .....	530	33 mo.	March, September
Chemistry .....	530	33 mo.	March, September
Electronics .....	530	33 mo.	March, September



**ADVANCED SCIENCE PROGRAMS  
CURRICULUM NUMBER 380**

**Chemistry**  
**Hydrodynamics**  
**Material Science**  
**General Physics**  
**Nuclear Physics**  
**Applied Mathematics**

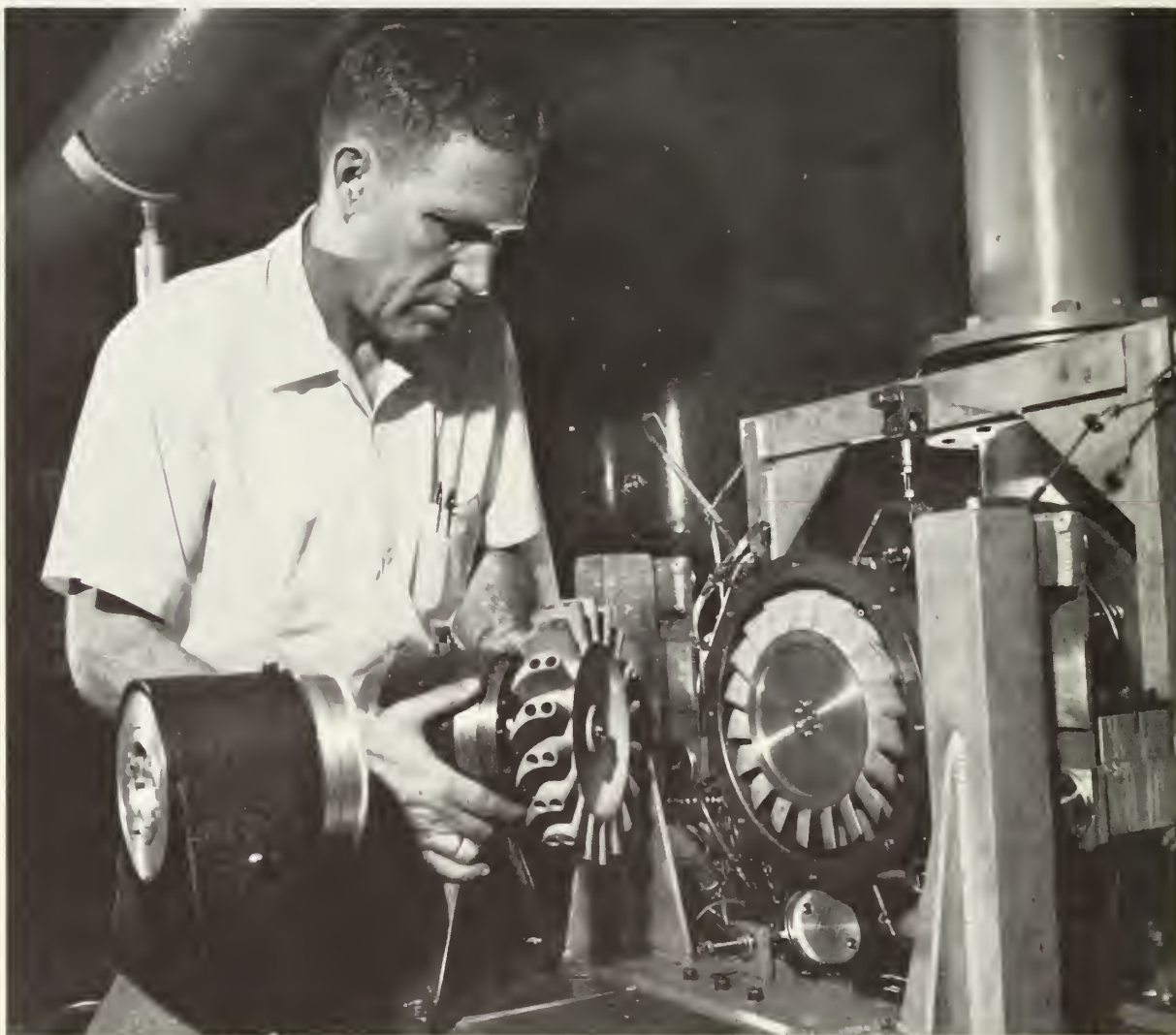
**OBJECTIVE**—To prepare selected officer personnel to deal with the problem of fundamental and applied research in the fields of general physics, nuclear physics, hydrodynamics, chemistry, material science, and applied mathematics.

**QUALIFICATIONS FOR ADMISSION**—Officers nominated for Advanced Science Curricula are selected from among those

first-year students enrolled in technical curricula at the Postgraduate School who apply for the Advanced Science Program. Applicants are carefully screened and only those having a very good academic background and who appear to have an excellent chance of succeeding in their chosen field are nominated to the Chief of Naval Personnel.

**DESCRIPTION**—Officers selected for Advanced Science Curricula complete their first year at the Naval Postgraduate School, and may spend their second and third years of study at a selected civilian university. The curriculum at the civilian university for each officer is arranged from courses selected to suit the needs of the Navy, to develop the capabilities of the individual student, and to meet the ultimate objective of his specialty.

The Advanced Science Curricula normally lead to the Master of Science degree for those officers meeting the requirements for that degree.



*Technician Demonstrating the Transonic Turbine Test Rig in the Aeronautics Department*

## AERONAUTICAL ENGINEERING PROGRAM CURRICULUM NUMBER 610

ROBERT STANLEY HUTCHES, Commander, U.S. Navy; Curricular Officer; B.S., Naval Academy, 1945; B.S. in Aeronautical Engineering, Naval Postgraduate School, 1953; M.S., Aeronautical Engineering, Univ. of Minnesota, 1954; Naval War College, 1962.

CHARLES HORACE KAHR, JR., Academic Associate (1947); B.S., Univ. of Michigan, 1944; M.S., 1945.

**OBJECTIVE**—To provide officers with advanced aeronautical education to meet Navy technical requirements in flight vehicles and their environmental fields. Curricula are edited to suit the field of the major, choosing fundamental or advanced material from mathematics, mechanics, physics, chemistry, metallurgy, structural analysis, aerodynamics, propulsion, electricity, electronics, environmental and vehicle dynamics; also the application of these sciences to flight vehicles and to space technology.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with a grade average of B or better in mathematics, physical sciences, and engineering is required. Completion of mathematics through differential and integral calculus, one year of engineering physics, one year of chemistry, and approximately 30 semester hours of basic engineering and 14 semester hours of electrical engineering is considered to be minimal preparation.

**DESCRIPTION**—First year courses of study are listed below in a sequence of academic quarters following entrance, and include the refresher material usually required, commensurate with the time elapsed from previous academic experience for the majority of officer students.

After three academic Quarters on board, students may be nominated for candidacy in one of the graduate curricular options: aerospace dynamics, flight structures, propulsion, avionics, or weapons systems. Representative courses to suit the option are tabulated below. Students who continue high scholastic achievement may be admitted to a third year either at this School or at one of the civilian institutions listed.

Students who do not enter candidacy for a graduate curriculum may continue in one of the second-year options listed leading to the B.S. (A.E.) Degree. Typical courses are listed herein.

### AERONAUTICAL ENGINEERING First Three Quarters COMMON CORE

#### *First Quarter*

AE 2201	Aero-Structures I .....	3- 2
AE 2301	Technical Aerodynamics .....	3- 0
AE 2401	Engineering Thermodynamics.....	3- 2
AE 2801	Aero-Laboratories, Introduction to.....	0- 3
MA 1100	Calculus Review .....	4- 0
		13- 7

#### *Second Quarter*

AE 2202	Aero-Structures II .....	3- 2
AE 2302	Theory of Airfoil and Wing.....	3- 2
AE 2402	Elementary Gas Dynamics.....	3- 2
AE 2802	Aero-Structures Laboratory.....	0- 3
MA 2121	Differential Equations and Infinite Series	4- 0
		13- 9

#### *Third Quarter*

AE 3115	Engineering Dynamics I.....	3- 2
AE 3303	Aircraft Performance .....	3- 2
AE 3403	Heat Transfer.....	3- 2
AE 3803	Subsonic Laboratory .....	0- 3
MA 3181	Vector Analysis .....	3- 0
		12- 9

After three quarters on board, students are selected for either graduate or undergraduate sequences.

### AERONAUTICAL ENGINEERING Two Year B.S.(A.E.) Group AF - FLIGHT PERFORMANCE

#### *Fourth Quarter*

AE 3321	Flight Dynamics I .....	3- 2
AE 3404	Aircraft Propulsion .....	3- 2
EE 2101	Principles of Electrical Engineering.....	3- 2
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		13- 6

#### *Fifth Quarter*

AE 3322	Flight Dynamics II .....	3- 2
AE 3501	Fluid Dynamics I .....	4- 0
EE 2102	Circuit Analysis .....	4- 2
PS 3112	Probability and Statistics .....	4- 0
		15- 4

#### *Sixth Quarter*

AE 3331	Flight Evaluation Techniques I.....	2- 0
AE 3340	Fundamentals of Automatic Controls.....	3- 2
AE 3502	Fluid Dynamics II.....	4- 0
AE 3804	Gas Dynamics and Propulsion Laboratory	0- 3
AE 3831	Flight Evaluation Techniques I Laboratory	0- 4
MN 3941	Engineering Economics .....	4- 0
		13- 9

#### *Seventh Quarter*

AE 3332	Flight Evaluation Techniques II.....	2- 0
*AE 3271	Fundamentals of Flight Vehicle Design....	3- 3
AE 3832	Flight Evaluation Techniques II Laboratory .....	0- 4
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
		12- 9

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Seventh Quarter.

**AERONAUTICAL ENGINEERING****Two Year B.S.(A.E.)****Group AG - AERONAUTICAL ENGINEERING (GENERAL)***Fourth Quarter*

AE 3321	Flight Dynamics I.....	3- 2
AE 3404	Aircraft Propulsion .....	3- 2
EE 2101	Principles of Electrical Engineering.....	3- 2
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		<hr/> 13- 6

*Fifth Quarter*

AE 3322	Flight Dynamics II.....	3- 2
AE 3501	Fluid Dynamics I.....	4- 0
EE 2102	Circuit Analysis .....	4- 2
PS 3112	Probability and Statistics.....	4- 0
		<hr/> 15- 4

*Sixth Quarter*

AE 3211	Aero-Structural Performance I.....	3- 2
AE 3340	Fundamentals of Automatic Controls.....	3- 2
AE 3502	Fluid Dynamics II.....	4- 0
AE 3804	Gas Dynamics and Propulsion Laboratory	0- 3
MN 3941	Engineering Economics .....	4- 0
		<hr/> 14- 7

*Seventh Quarter*

AE 3212	Aero-Structural Performance II.....	3- 2
*AE 3271	Fundamentals of Flight Vehicle Design....	3- 3
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
		<hr/> 13- 7

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Seventh Quarter.

**AERONAUTICAL ENGINEERING****Two Year M.S.(A.E.)****Group AA - AERODYNAMICS (FLIGHT DYNAMICS)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		<hr/> 15- 5

*Fifth Quarter*

AE 4304	Flight Vehicle Response.....	3- 2
AE 3804	Gas Dynamics and Propulsion Laboratory	0- 3
AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
EE 2221	Electronics Fundamentals .....	3- 2
PS 3112	Probability and Statistics.....	4- 0
		<hr/> 14- 7

*Sixth Quarter*

AT 4336	Low Speed Flight Mechanics.....	3- 2
AE 3341	Control Systems .....	3- 3
*MN 3941	Engineering Economics .....	4- 0
	Thesis .....	4- 0
		<hr/> 14- 5

\* Substitute GV 1368 for Allied Officers (3-0).

*Seventh Quarter*

AE 4342	Automatic Control I.....	3- 2
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
	Thesis .....	4- 0
		<hr/> 14- 4

Graduate at end of Seventh Quarter.

**AERONAUTICAL ENGINEERING****Three Year - Ae.E.****Group AA - AERODYNAMICS (FLIGHT DYNAMICS)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		<hr/> 15- 5

*Fifth Quarter*

AE 4304	Flight Vehicle Response.....	3- 2
AE 3804	Gas Dynamics and Propulsion Laboratory	0- 3
AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
EE 2221	Electronics Fundamentals .....	3- 2
PS 3112	Probability and Statistics .....	4- 0
		<hr/> 14- 7

*Sixth Quarter*

AE 3341	Control Systems .....	3- 3
AE 4522	Boundary Layer Flows .....	4- 0
MA 3172	Complex Variables .....	4- 0
MN 3941	Engineering Economics .....	4- 0
		<hr/> 15- 3

*Seventh Quarter*

AE 4342	Automatic Control I .....	3- 2
AE 4523	Fundamentals of Compressible Flow.....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
		<hr/> 14- 4

*Eighth Quarter*

MA 3042	Linear Algebra .....	5- 0
	Thesis .....	4- 0
	(Above course to be given at accelerated rate for six weeks. Remaining six weeks of quarter will be spent on Industrial Tour.)	
		<hr/> 9- 0



*Ninth Quarter*

AE 4431	Aerothermodynamics of Turbo-Machines....	4- 0
AE 4851	Turbomachinery Laboratory I.....	0- 3
AE 4524	Supersonic Aerodynamics .....	4- 0
AE 4541	Missile Technology I.....	4- 0
	Thesis .....	4- 0
		<hr/> 16- 3

*Tenth Quarter*

AE 4336	Low Speed Flight Mechanics.....	3- 2
AE 4542	Missile Technology II.....	4- 0
	Elective .....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 2

*Eleventh Quarter*

AE 4275	Advanced Flight Vehicle Design.....	3- 3
AE 4543	Missile Technology III.....	4- 0
	*Elective .....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 3

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Eleventh Quarter.

**AERONAUTICAL ENGINEERING****Two Year M.S.(A.E.)****Group AD - AERODYNAMICS (GAS DYNAMICS)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		<hr/> 15- 5

*Fifth Quarter*

AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
AE 4523	Fundamentals of Compressible Flow.....	4- 0
EE 2221	Electronics Fundamentals .....	3- 2
PS 3112	Probability and Statistics.....	4- 0
		<hr/> 15- 2

*Sixth Quarter*

AE 4336	Low Speed Flight Mechanics.....	3- 2
AE 4522	Boundary Layer Flows.....	4- 0
*MN 3941	Engineering Economics .....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 2

\* Substitute GV 1368 for Allied Officers (3-0).

*Seventh Quarter*

AE 4524	Supersonic Aerodynamics .....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 2

Graduate at end of Seventh Quarter.

**AERONAUTICAL ENGINEERING****Three Year Ae.E.****Group AD - AERODYNAMICS (GAS DYNAMICS)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		<hr/> 15- 5

*Fifth Quarter*

AE 4431	Aerothermodynamics of Turbo-Machines....	4- 0
AE 4851	Turbomachinery Laboratory I.....	0- 3
AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
EE 2221	Electronics Fundamentals .....	3- 2
PS 3112	Probability and Statistics .....	4- 0
		<hr/> 15- 5

*Sixth Quarter*

AE 4461	Statistical Thermodynamics .....	3- 2
AE 4522	Boundary Layer Flows .....	4- 0
MA 3172	Complex Variables .....	4- 0
MN 3941	Engineering Economics .....	4- 0
		<hr/> 15- 2

*Seventh Quarter*

AE 4462	Combustion Thermodynamics I.....	3- 2
AE 4523	Fundamentals of Compressible Flow.....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
		<hr/> 14- 4

*Eighth Quarter*

MA 3042	Linear Algebra .....	5- 0
	Thesis .....	4- 0
	(Above course to be given at accelerated rate for six weeks. Remaining six weeks of this quarter will be spent on Industrial Tour.)	
		<hr/> 9- 0

*Ninth Quarter*

AE 4463	Combustion Thermodynamics II.....	3- 2
AE 4524	Supersonic Aerodynamics .....	4- 0
AE 4541	Missile Technology I.....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 2

*Tenth Quarter*

AE 4336	Low Speed Flight Mechanics.....	3- 2
AE 4464	Aerothermochemistry .....	3- 2
AE 4542	Missile Technology II.....	4- 0
	Thesis .....	4- 0
		<hr/> 14- 4

*Eleventh Quarter*

AE 4275	Advanced Flight Vehicle Design.....	3- 3
AE 4543	Missile Technology III.....	4- 0
	*Elective .....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 3

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Eleventh Quarter.

**AERONAUTICAL ENGINEERING****Two Year M.S.(A.E.)****Group AR - FLIGHT PROPULSION (ROCKETS)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		15- 5

*Fifth Quarter*

AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
AE 4523	Fundamentals of Compressible Flow.....	4- 0
EE 2221	Electronics Fundamentals I.....	3- 2
PS 3112	Probability and Statistics.....	4- 0
		15- 2

*Sixth Quarter*

AE 4461	Statistical Thermodynamics .....	3- 2
AE 4522	Boundary Layer Flows.....	4- 0
*MN 3941	Engineering Economics .....	4- 0
	Thesis .....	4- 0
		15- 2

\* Substitute GV 1368 for Allied Officers (3-0).

*Seventh Quarter*

AE 4462	Combustion Thermodynamics I.....	3- 2
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
	Thesis .....	4- 0
		14- 4

Graduate at end of Seventh Quarter.

**AERONAUTICAL ENGINEERING****Three Year Ae.E.****Group AR - FLIGHT PROPULSION (ROCKETS)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		15- 5

*Fifth Quarter*

AE 4431	Aerothermodynamics of Turbo-Machines..	4- 0
AE 4851	Turbomachinery Laboratory I.....	0- 3
AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
EE 2221	Electronics Fundamentals I .....	3- 2
PS 3112	Probability and Statistics.....	4- 0
		15- 5

*Sixth Quarter*

AE 4461	Statistical Thermodynamics .....	3- 2
AE 4522	Boundary Layer Flows.....	4- 0
MA 3172	Complex Variables .....	4- 0
MN 3941	Engineering Economics .....	4- 0
		15- 2

*Seventh Quarter*

AE 4462	Combustion Thermodynamics I.....	3- 2
AE 4523	Fundamentals of Compressible Flow.....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
		14- 4

*Eighth Quarter*

MA 3042	Linear Algebra .....	5- 0
	Thesis .....	4- 0
	(Above course to be given at accelerated rate for six weeks. Remaining six weeks of this quarter will be spent on Industrial Tour.)	
		9- 0

*Ninth Quarter*

AE 4463	Combustion Thermodynamics II.....	3- 2
AE 4524	Supersonic Aerodynamics .....	4- 0
AE 4541	Missile Technology I.....	4- 0
	Thesis .....	4- 0
		15- 2

*Tenth Quarter*

AE 4464	Aerothermochemistry .....	3- 2
AE 4542	Missile Technology II.....	4- 0
	Elective .....	4- 0
	Thesis .....	4- 0
		15- 2

*Eleventh Quarter*

AE 4275	Advanced Flight Vehicle Design.....	3- 3
AE 4543	Missile Technology III.....	4- 0
	*Elective .....	4- 0
	Thesis .....	4- 0
		15- 3

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Eleventh Quarter.

**AERONAUTICAL ENGINEERING****Two Year M.S.(A.E.)****Group AS - FLIGHT STRUCTURES***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
		15- 5

*Fifth Quarter*

AE 4241	Flight Vehicle Structural Analysis.....	3- 2
AE 4251	Advanced Structural Dynamics.....	4- 0
PS 3112	Probability and Statistics.....	4- 0
EE 2221	Electronics Fundamentals .....	3- 2
		<hr/> 14- 4

*Sixth Quarter*

AE 4242	Theory of Plate and Shell Structures.....	3- 2
AE 4252	Advanced Aeroelasticity .....	4- 0
*MN 3941	Engineering Economics .....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 2

\* Substitute GV 1368 for Allied Officers (3-0).

*Seventh Quarter*

AE 4161	Theory of Viscoelasticity .....	4- 0
AE 4162	Theory of Plasticity .....	4- 0
OA 3204	Systems Analysis .....	4- 0
	Thesis .....	4- 0
		<hr/> 16- 0

Graduate at end of Seventh Quarter.

**AERONAUTICAL ENGINEERING****Three Year Ae.E.****Group AS - FLIGHT STRUCTURES***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
		<hr/> 15- 5

*Fifth Quarter*

AE 4241	Flight Vehicle Structural Analysis.....	3- 2
AE 4132	Solid Mechanics I.....	4- 0
PS 3112	Probability and Statistics.....	4- 0
EE 2221	Electronics Fundamentals.....	3- 2
		<hr/> 14- 4

*Sixth Quarter*

AE 4133	Solid Mechanics II.....	4- 0
AE 4242	Theory of Plate and Shell Structures.....	3- 2
MN 3941	Engineering Economics .....	4- 0
MA 3172	Complex Variables .....	4- 0
		<hr/> 15- 2

*Seventh Quarter*

AE 4431	Aerothermodynamics of Turbo-Machines..	4- 0
AE 4851	Turbomachinery Laboratory I .....	0- 3
AE 4523	Fundamentals of Compressible Flow.....	4- 0
OA 3204	Systems Analysis .....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
		<hr/> 15- 5

*Eighth Quarter*

MA 3042	Linear Algebra .....	5- 0
	Thesis .....	4- 0
		(Above course to be given at accelerated rate for six weeks. Remaining six weeks of this quarter will be spent on Industrial Tour.)
		<hr/> 9- 0

*Ninth Quarter*

AE 3804	Gas Dynamics and Propulsion Laboratory	0- 3
AE 4251	Advanced Structural Dynamics .....	4- 0
AE 4161	Theory of Viscoelasticity .....	4- 0
AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
	Thesis .....	4- 0
		<hr/> 16- 3

*Tenth Quarter*

AE 4252	Advanced Aeroelasticity .....	4- 0
AE 4522	Boundary Layer Flows.....	4- 0
	Elective .....	4- 0
	Thesis .....	4- 0
		<hr/> 16- 0

*Eleventh Quarter*

AE 4162	Theory of Plasticity .....	4- 0
AE 4275	Advanced Flight Vehicle Design.....	3- 3
	*Elective .....	4- 0
	Thesis .....	4- 0
		<hr/> 15- 3

\* Substitute GV 1368 for Allied Officers (3-0).

**AERONAUTICAL ENGINEERING****Two Year M.S.(A.E.)****Group AT - FLIGHT PROPULSION (ROTATING MACHINERY)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II .....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		<hr/> 15- 5

*Fifth Quarter*

AE 4431	Aerothermodynamics of Turbo-Machines..	4- 0
AE 4851	Turbomachinery Laboratory I .....	0- 3
AE 4521	Vector Mechanics of Fluid Flow.....	4- 0
EE 2221	Electronics Fundamentals .....	3- 2
PS 3112	Probability and Statistics .....	4- 0
		<hr/> 15- 5

*Sixth Quarter*

AE 4432	Advanced Theory of Turbo-Machines.....	4- 0
AE 4852	Turbomachinery Laboratory II .....	0- 3
AE 4522	Boundary Layer Flows.....	4- 0
*MN 3941	Engineering Economics .....	4- 0
	Thesis .....	4- 0
		<hr/> 16- 3

\* Substitute GV 1368 for Allied Officers (3-0).

*Seventh Quarter*

AE 3804	Gas Dynamics and Propulsion Laboratory	0- 3
AE 4523	Fundamentals of Compressible Flow.....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
	Thesis .....	4- 0
		15- 5

Graduate at end of Seventh Quarter.

**AERONAUTICAL ENGINEERING****Three Year Ae.E.****Group AT - FLIGHT PROPULSION (ROTATING MACHINERY)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II .....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		15- 5

*Fifth Quarter*

AE 4431	Aerothermodynamics of Turbo-Machines....	4- 0
AE 4851	Turbomachinery Laboratory I .....	0- 3
AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
EE 2221	Electronics Fundamentals .....	3- 2
PS 3112	Probability and Statistics .....	4- 0
		15- 5

*Sixth Quarter*

AE 4432	Advanced Theory of Turbo-Machines.....	4- 0
AE 4852	Turbomachinery Laboratory II .....	0- 3
AE 4522	Boundary Layer Flows.....	4- 0
MA 3172	Complex Variables .....	4- 0
MN 3941	Engineering Economics .....	4- 0
		16- 3

*Seventh Quarter*

AE 3804	Gas Dynamics and Propulsion Laboratory	0- 3
AE 4161	Viscoelasticity .....	4- 0
AE 4523	Fundamentals of Compressible Flow.....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
OA 3204	Systems Analysis .....	4- 0
		15- 5

*Eighth Quarter*

MA 3042	Linear Algebra .....	5- 0
	Thesis .....	4- 0
(Above course to be given at accelerated rate for six weeks. Remaining six weeks of this quarter will be spent on Industrial Tour.)		
		9- 0

*Ninth Quarter*

AE 4421	Heat Transfer I .....	4- 0
AE 4433	Advanced Turbo-Propulsion Systems.....	4- 0
AE 4524	Supersonic Aerodynamics .....	4- 0
	Thesis .....	4- 0
		16- 0

*Tenth Quarter*

AE 4336	Low Speed Flight Mechanics.....	3- 2
AE 4422	Heat Transfer II .....	4- 0
AE 4434	Turbo-Propulsion Seminar .....	3- 0
AE 4854	Turbo-Machinery Laboratory III .....	0- 3
	Thesis .....	4- 0
		14- 5

*Eleventh Quarter*

AE 4275	Advanced Flight Vehicle Design.....	3- 3
AE 4423	Heat Transfer III .....	4- 0
	*Elective .....	4- 0
	Thesis .....	4- 0
		15- 3

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Eleventh Quarter.

**AERONAUTICAL ENGINEERING****Two Year M.S.(A.E.)****Group AW - AIR WEAPONS SYSTEMS (EXPLOSIVE ORDNANCE)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		15- 5

*Fifth Quarter*

AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
AE 4523	Fundamentals of Compressible Flow.....	4- 0
CH 2001	General Principles of Chemistry.....	3- 2
PS 3112	Probability and Statistics .....	4- 0
		15- 2

*Sixth Quarter*

AE 4461	Statistical Thermodynamics .....	3- 2
AE 4522	Boundary Layer Flows.....	4- 0
CH 3709	Explosives Chemistry .....	3- 2
	Thesis .....	4- 0
		14- 4

*Seventh Quarter*

AE 4462	Combustion Thermodynamics I.....	3- 2
MS 2218	Elements of Engineering Materials.....	3- 2
*OA 3204	Systems Analysis .....	4- 0
	Thesis .....	4- 0
		14- 4

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Seventh Quarter.



**AERONAUTICAL ENGINEERING****Three Year Ae.E.****Group AW - AIR WEAPONS SYSTEMS  
(EXPLOSIVE ORDNANCE)***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		15- 5

*Fifth Quarter*

AE 4431	Aerothermodynamics of Turbo-Machines..	4- 0
AE 4851	Turbo-Machinery Laboratory I .....	0- 3
AE 4521	Vector and Tensor Mechanics of Fluid Flow .....	4- 0
CH 2001	General Principles of Chemistry.....	3- 2
PS 3112	Probability and Statistics .....	4- 0
		15- 5

*Sixth Quarter*

AE 4461	Statistical Thermodynamics .....	3- 2
AE 4522	Boundary Layer Flows .....	4- 0
MA 3172	Complex Variables .....	4- 0
CH 2402	Introduction to Physical Chemistry.....	3- 3
		14- 5

*Seventh Quarter*

AE 4462	Combustion Thermodynamics I .....	3- 2
AE 4523	Fundamentals of Compressible Flow.....	4- 0
MS 2218	Elements of Engineering Materials.....	3- 2
*OA 3204	Systems Analysis .....	4- 0
		14- 4

\* Substitute GV 1368 for Allied Officers (3-0).

*Eighth Quarter*

CH 4800	Special Topics .....	2- 0 to 4- 0
	Thesis .....	4- 0
		(Above course to be given at accelerated rate for six weeks. Remaining six weeks of this quarter will be spent on Industrial Tour.)
		6- 0 to 8- 0

*Ninth Quarter*

AE 4463	Combustion Thermodynamics II .....	3- 2
AE 4524	Supersonic Aerodynamics .....	4- 0
AE 4541	Missile Technology I .....	4- 0
	Thesis .....	4- 0
		15- 2

*Tenth Quarter*

AE 4464	Aerothermochemistry .....	3- 2
AE 4542	Missile Technology II .....	4- 0
CH 3709	Explosives Chemistry .....	3- 2
	Thesis .....	4- 0
		14- 4

*Eleventh Quarter*

*AE 4275	Flight Vehicle Design .....	3- 3
AE 4543	Missile Technology III .....	4- 0
CH 3713	Blast and Shock Effects.....	3- 0
	Thesis .....	4- 0
		14- 3

\* Substitute GV 1368 for Allied Officers (3-0).

Graduate at end of Eleventh Quarter.

**AERONAUTICAL ENGINEERING****Three Year Ae.E.****Group AX - AEROELECTRONICS***Fourth Quarter*

AE 3805	Engineering Dynamics Laboratory.....	0- 3
AE 4116	Engineering Dynamics II.....	3- 2
MA 3172	Complex Variables .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
EE 2101	Principles of Electrical Engineering.....	3- 2
		14- 7

*Fifth Quarter*

AE 4304	Stability Response .....	4- 0
EE 2102	Circuit Analysis .....	4- 2
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
PS 3112	Probability and Statistics .....	4- 0
		16- 2

*Sixth Quarter*

AE 4131	Continuum Mechanics .....	4- 0
AE 3341	Control Systems .....	3- 3
EE 2211	Electronic Engineering Fundamentals I....	4- 2
EE 3103	Linear Systems Analysis .....	3- 3
		14- 8

*Seventh Quarter*

AE 4342	Automatic Control I .....	3- 2
AE 4523	Fundamentals of Compressible Flow.....	4- 0
EE 2212	Electronic Engineering Fundamentals II....	4- 3
EE 3412	Non-linear and Sampled Systems.....	3- 3
		14- 8

*Eighth Quarter*

AE 4336	Low Speed Flight Mechanics.....	3- 2
EE 2214	Electronic Pulse and Digital Circuits.....	4- 3
EE 3621	Electromagnetics I .....	3- 1
	Thesis .....	4- 0
		14- 6

*Ninth Quarter*

AE 4275	Advanced Flight Vehicle Design.....	3- 3
EE 3622	Electromagnetics II .....	3- 0
EE 3114	Communication Theory I .....	4- 0
	Thesis .....	4- 0
		14- 3



*Tenth Quarter*

AE 4461	Statistical Thermodynamics .....	3- 2
EE 4433	Radar Systems .....	3- 2
EE 4571	Statistical Communication Theory .....	3- 2
	Thesis .....	4- 0
		13- 6

*Eleventh Quarter*

AE 4343	Automatic Control II .....	3- 2
EE 4473	Missile Guidance Systems .....	3- 0
EE 4461	Systems Engineering .....	3- 1
	Thesis .....	4- 0
		13- 3

Graduate at end of Eleventh Quarter.

**AERONAUTICAL ENGINEERING  
M.S.(A.E.)  
NAVAL ACADEMY DIRECT INPUT**

*First Quarter*

AE 3805	Engineering Dynamics Laboratory. ....	0- 3
AE 4116	Engineering Dynamics II .....	3- 2
AE 4131	Continuum Mechanics .....	4- 0
AE 4522	Boundary Layer Flows .....	4- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
		15- 5

*Second Quarter*

AE	Sequence #1 .....	4- 0
AE	Sequence #2 .....	4- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
	Thesis .....	4- 0
		16- 0

*Third Quarter*

AE	Sequence #1 .....	4- 0
AE	Sequence #2 .....	4- 0
	Elective .....	4- 0
	Thesis .....	4- 0
		16- 0

Graduate at end of Third Quarter.

Note: Sequences #1 and #2 above are to be selected from the options offered in the areas of Aerodynamics, Flight Dynamics, Flight Propulsion, and Flight Structures.

Civilian universities currently used in third year work and the fields in which they provide the strongest competence for advanced study are as follows:

CALIFORNIA INST. OF TECHNOLOGY,  
PASADENA, CALIF.

Gas Dynamics  
Structures  
Jet Propulsion

MASSACHUSETTS INST. OF TECHNOLOGY,  
CAMBRIDGE, MASS.

Astronautics  
Airborne Weapons Systems

PRINCETON UNIVERSITY, PRINCETON, N.J.

Flight Mechanics  
Gas Dynamics  
Propulsion (Rockets)

COLLEGE OF AERONAUTICS, CRANFIELD, ENGLAND

Aerodynamics  
Aircraft Design  
Aircraft Electronics  
Guidance and Control

STANFORD UNIVERSITY, PALO ALTO, CALIF.

Aero- and Gas Dynamics  
Structures  
Guidance and Control

**BACCALAUREATE PROGRAMS****Curriculum Number 461**

HAROLD EDWARD COLLINS, Commander, U.S. Navy, Curricular Officer; B.S., Naval Academy, 1952; B.S. in Engineering Electronics, Naval Postgraduate School, 1958.

RAYMOND KENNETH HOUSTON, Academic Associate; B.S., Worcester Polytechnic Institute, 1933; M.S., 1939.

WAYNE CHESTER BENDER, Lieutenant Commander, U.S. Navy, Assistant Curricular Officer; B.S.Ed., State Teachers College, Millersville, Pennsylvania, 1957.

**OBJECTIVES**—To raise the educational level, broaden the mental outlook, and increase the professional and scientific knowledge of naval officers who do not have a baccalaureate degree.

**QUALIFICATION FOR ADMISSION**—Applicants must have an advanced undergraduate standing of at least 45 semester hours of acceptable credit, and have earned a C average in all previous college courses. Acceptable undergraduate work must include mathematics through College Algebra. A minimum of 15 semester hours is required from an accredited educational institution since a maximum of 30 semester hours credit will be allowed for service schools.

**DESCRIPTION**—The Baccalaureate curricula provide specialized study to meet the professional needs of the commissioned officer. The different educational backgrounds and personal needs of the students are accommodated by providing two curricula.

The Bachelor of Science curriculum emphasizes the physical environment without neglecting the social. It consists of 180 quarter hours distributed as follows: 100 in Science and Engineering; 36 in Government and Humanities; and 44 in electives and/or transfer credit. Successful completion leads to the award of the degree Bachelor of Science in Engineering Science.

The Bachelor of Arts curriculum emphasizes the social environment without neglecting the physical. It consists of 180 quarter hours distributed as follows: 100 in Government and Humanities; 36 in the Physical Sciences; and 44 in electives and/or transfer credit. Successful completion leads to the award of the degree Bachelor of Arts with a major in Government (International Relations).

Classes for both curricula convene in January and July. From one to two calendar years are allowed to complete the program. Students pursuing these curricula carry an average load of 16 credit hours per quarter.

**BACHELOR OF SCIENCE IN ENGINEERING SCIENCE***First Quarter*

CH 1001	Introductory General Chemistry I.....	4-2
MA 1021	College Algebra and Trigonometry.....	4-0
GV 1060	U.S. Government .....	3-0
EN 2010	Advanced Writing .....	3-0
		14-2

*Second Quarter*

CH 1002	Introductory General Chemistry II.....	3-2
MA 1105	Calculus and Analytic Geometry I.....	5-0
SP 1020	Public Speaking .....	3-0
HI 2032	U.S. History (1865-present) .....	3-0
LT 1040	Appreciation of Literature .....	3-0
		17-2

*Third Quarter*

MS 1021	Elements of Materials Science I.....	3-2
MA 1106	Calculus and Analytic Geometry II.....	5-0
PH 1015	General Physics I.....	4-3
SP 1021	Conference Procedures .....	2-0
		14-5

*Fourth Quarter*

MS 1022	Elements of Materials Science II.....	2-2
MA 1107	Calculus and Analytic Geometry III.....	3-0
PH 1016	General Physics II .....	4-3
HI 2030	European History (1914-1950).....	3-0
PS 2331	Elementary Probability and Statistics.....	4-1
		16-6

*Fifth Quarter*

ME 2120	Elements of Engineering Thermodynamics .....	3-2
PH 2017	General Physics III .....	4-2
EE 2221	Electronics Fundamentals .....	3-2
GV 2061	National Security .....	3-0
		13-6

*Sixth Quarter*

EE 2223	Intermediate Electronics .....	3-3
MN 3941	Engineering Economics .....	4-0
ME 2562	Space Flight Dynamics .....	4-0
CS 2100	Introduction to Computers and Programming .....	4-0
		15-3

*Seventh Quarter*

OC 2110	Introduction to Oceanography .....	3-0
EE 2224	Communications Electronics .....	4-3
OA 2201	Elements of Ops Research/Systems Analysis .....	4-0
AO 2301	Aero Engineering for Aviators.....	4-2
		15-5

*Eighth Quarter*

AO 2302	Accident Prevention and Crash Investigation (Aviators) .....	3- 2
PY 2050	General Psychology .....	3- 0
	Electives (Science/Engineering).....	12- 0
		<hr/> 18- 2

**BACHELOR OF ARTS  
WITH MAJOR IN GOVERNMENT  
(INTERNATIONAL RELATIONS)**

*First Quarter*

EN 2010	Advanced Writing .....	3-0
GV 1060	U.S. Government .....	3-0
HI 2131	U.S. History (1763-1865) .....	3-0
MA 1010	Intermediate Algebra .....	4-0
		13-0

*Second Quarter*

SP 1020	Public Speaking .....	3- 0
HI 2032	U.S. History (1865-present) .....	3- 0
LT 1040	Appreciation of Literature.....	3- 0
MA 1021	College Algebra and Trigonometry.....	4- 0
		<hr/> 13- 0

*Third Quarter*

OC 2110	Introduction to Oceanography .....	3- 0
HI 2130	European History (1815-1914) .....	3- 0
GV 2160	Comparative Government .....	4- 0
MN 2530	Introduction to Economics.....	4- 0
SP 2021	Conference Procedures .....	2- 0
		<hr/> 16- 0

*Fourth Quarter*

PH 1005	General Physics I .....	3- 2
GV 2161	Introduction to International Relations.....	3- 0
HI 2030	European History (1914-1950) .....	3- 0
MN 2541	Microeconomics .....	4- 0
PS 2311	Elementary Probability and Statistics.....	3- 0
		<hr/> 16- 2

*Fifth Quarter*

GV 2061	National Security .....	3- 0
GV 2163	Political Thought .....	4- 0
PH 1006	General Physics II .....	3- 2
Electives (Government/Humanities) .....		4- 0
		<hr/> 14- 2

*Sixth Quarter*

CS 2100	Introduction to Computers and Programming .....	4- 0
GV 2164	Comparative Ideologies .....	3- 0
PH 1007	General Physics III .....	4- 2
Electives (Government/Humanities) .....		7- 0
		<hr/> 18- 2

*Seventh Quarter*

AO 2301	Aero Engineering for Aviators.....	4- 2
Electives (Government/Humanities) .....		12- 0
		<hr/> 16- 2

*Eighth Quarter*

PY 2050	General Psychology .....	3- 0
AO 2302	Accident Prevention and Crash Investigation .....	3- 2
Electives (Government/Humanities) .....		12- 0
		<hr/> 18- 2

## ELECTRONICS AND COMMUNICATIONS ENGINEERING PROGRAMS

### CURRICULA NUMBERS 472, 590, 600 and 620

ROBERT EDWARD SHELDON, Commander, U.S. Navy; Curricular Officer; B.S., Naval Academy, 1952; B.S. in Engr. Electronics, Naval Postgraduate School, 1959.

ABRAHAM SHEINGOLD, Academic Associate; B.S., College of the City of New York, 1936; M.S., 1937.

ROY ELWOOD LAWTON, Lieutenant, U.S. Navy; Assistant Curricular Officer; B.S.E.E., Univ. of Washington, 1961.

**OBJECTIVE**—The Engineering Electronics and Communications Engineering Programs (472, 590 and 600) are designed to provide officers with an education of significant depth in the basic scientific and engineering fields related to electronics and communications. Courses in Management and Operations Analysis and Research are included to complete the education deemed necessary to fill the military service requirement for specialist and subspecialist officers within its career-officer corps.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree is required for admission. Inasmuch as the initial courses constitute a rapid and thorough review of the basic science-engineering disciplines, a background with an above average pattern of grades in differential and integral calculus and physics is considered essential.

**DESCRIPTION**—Officers enrolled in Electronics or Communications Engineering normally enter a basic core curriculum for the first three quarters. However, those with recent and appropriate academic backgrounds may be placed in a correspondingly advanced program. CURRICULUM NUMBER 472, a special Electronics Curriculum for CEC officers with a recent B.S.E.E. degree, would be typical of such an advanced program. These advanced programs are tailored in content and length depending on the individual student backgrounds and are not delineated here. Special curricula formulated by the Curricular Officer and Academic Associate, when differing significantly from the "standard" curricula below, are individually approved by the Academic Council.

At the end of the first three quarters, officers are nominated either for the advanced 3-year curriculum or for the 2-year curriculum. This nomination is based upon the Superintendent's appraisal of the individual's academic performance and is subject to final approval by the Chief of Naval Personnel based on personnel assignment considerations.

For properly qualified entering students, successful completion of the 2-year curricula leads to the award of a Bachelor of Science degree, while successful completion of the 3-year curricula leads to the award of a Master of Science degree in Electrical Engineering. Appropriate subspecialty codes (P-codes) are subsequently assigned by the Chief of Naval Personnel.

## BASIC CURRICULUM (Group EB)

### *First Quarter*

EE 2101	Principles of Electrical Engineering.....	3- 2
MA 1100	Calculus Review .....	4- 0
MA 2045	Introduction to Linear Algebra.....	3- 0
PH 1041	Review of Mechanics and Thermodynamics .....	4- 0
		14- 2

### *Second Quarter*

EE 2102	Circuit Analysis .....	4- 2
EE 2211	Electronic Engineering Fundamentals I....	4- 2
MA 2121	Differential Equations and Infinite Series .....	4- 0
PH 2241	Waves and Particles .....	4- 0
		16- 4

### *Third Quarter*

EE 3103	Linear Systems Analysis .....	3- 3
EE 2212	Electronic Engineering Fundamentals II....	4- 3
MA 3172	Complex Variables .....	4- 0
PH 3641	Atomic Physics .....	4- 2
		15- 8

## BS PROGRAM

The Engineering Electronics (590) and Communications Engineering (600) students in the 2-year BS program continue a common curriculum until the last two quarters when courses are oriented to the individual fields as indicated.

### *Fourth Quarter*

EE 2611	Electromagnetic Fields .....	3- 0
EE 2214	Electronic Pulse and Digital Circuits.....	4- 3
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
EE 2811	Digital Machines .....	2- 0
EE 3114	Communications Theory I .....	4- 0
		17- 3

### *Fifth Quarter*

EE 2612	Transmission of Electromagnetic Energy..	3- 1
EE 2213	Electronic Communications Circuits .....	4- 3
EE 2711	Electrical and Electronics Measurements..	3- 3
PS 2111	Introduction to Probability and Statistics I .....	4- 0
		14- 7

### *Sixth Quarter*

EE 3411	Control Systems .....	3- 3
EE 2215	Special Electronic Devices .....	4- 2
EE 3116	Communications Theory II .....	3- 2
or		
EE 2311	Principles of Energy Conversion.....	3- 2
EE 3432	Pulse Radar .....	3- 2
or		
EE 3422	Modern Communications .....	3- 2
		13- 9



*Seventh Quarter*

MN 2900	Management of Human Resources.....	4- 0
OA 2201	Elements of Operations Research/Systems Analysis .....	4- 0
EE 3631	Antenna Engineering and Propagation Theory .....	3- 2
*EE 3481	Radar and ECM .....	3- 2
	or	
*EE 3482	Communications ECM .....	3- 2
		14- 4

\* Substitute GV 1368, American Life and Institutions, for Allied Officers.

**MS PROGRAM**

The Engineering Electronics (590) and Communications Engineering (600) students in the 3-year MS program continue a common curriculum until their seventh quarter when elective courses are taken, oriented to their specific field. These courses are selected from the list following this section and must meet with the approval of the Curricular Officer and Academic Associate as being consistent with the major field of study.

The tenth quarter is set aside for the MS student to spend on an industrial tour at a civilian or military laboratory in the capacity of a junior engineer; work on a thesis related project at the PG School; or a combination of these employments.

Curriculum Number 590 GROUP EA, Advanced Electronics, Option I

GROUP EI, Information and Control, Option II

Curriculum Number 600 GROUP CE, Advanced Communications Engineering

*Fourth Quarter*

MA 2161	Introduction to Mathematical Physics.....	3- 0
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
EE 2214	Electronic Pulse and Digital Circuits.....	4- 3
EE 3114	Communications Theory I .....	4- 0
EE 2811	Digital Machines .....	2- 0
		17- 3

*Fifth Quarter*

PS 3112	Probability and Statistics .....	4- 0
EE 2213	Electronic Communications Circuits .....	4- 3
EE 3621	Electromagnetics I .....	3- 1
EE 2711	Electrical and Electronics Measurements..	3- 3
EE 0951	Thesis Seminar .....	0- 1
		14- 8

*Sixth Quarter*

EE 3411	Control Systems .....	3- 3
EE 3215	Advanced Electronic Devices .....	4- 2
EE 3622	Electromagnetics II .....	3- 0
EE 4571	Statistical Communication Theory .....	3- 2
EE 0951	Thesis Seminar .....	0- 1
		13- 8

*Seventh Quarter*

OA 3202	Methods of Operations Analysis/Systems Analysis .....	4- 0
EE 4121	Advanced Network Theory .....	3- 2
	Elective Sequence .....	3- 0 to 5- 0
PH 3741	Electronic Properties of Metals and Semi-Conductors .....	4- 2
EE 0951	Thesis Seminar .....	0- 1
		14- 5 to 16- 5

*Eighth Quarter*

EE 4541	Signal Processing .....	3- 1
EE 4433	Radar Systems .....	3- 2
	Elective Sequence .....	3- 0 to 5- 0
EE 0951	Thesis Seminar .....	0- 1
		9- 4 to 11- 4

*Ninth Quarter*

OA 3203	Survey of Operations Analysis/Systems Analysis .....	4- 0
MN 3941	Engineering Economics .....	4- 0
	Elective Sequence .....	3- 0 to 5- 0
EE 0951	Thesis Seminar .....	0- 1
		11- 1 to 13- 1

*Tenth Quarter*

EE 0951	Thesis Seminar .....	0- 1
	Industrial Tour and/or Supervised Project .....	0- 1

*Eleventh Quarter*

OA 3204	Systems Analysis .....	4- 0
	Elective Sequence .....	3- 0 to 5- 0
	Elective Sequence .....	3- 0 to 5- 0
EE 0951	Thesis Seminar .....	0- 1
		10- 1 to 14- 1

**ELECTIVE COURSES FOR MS STUDENTS**

Students in the Master of Science curricula will take elective courses in the seventh through eleventh quarters. Course selection will be made from the below list depending on the assigned curricula (Electronics or Advanced Communications) and Option within the Electronics curriculum (Options I or II). Electives selected must meet with the approval of the Curricular Officer and Academic Associate as being consistent with the major field of study.

OPTION I—Engineering Electronics (Advanced Electronics)

OPTION II—Engineering Electronics (Information and Control)

OPTION C—Advanced Communications Engineering

Quarter	Option	Course	Qtr. Hours
Seventh	I, C	EE 3263 Solid State Circuit Design .....	3-3
	I, C	EE 4652 Microwave Circuits and Measurements .....	3-2
	II	EE 3412 Non-Linear and Sampled Systems .....	3-3



Eighth	I, II	EE 3812	Logical Design and Circuitry .....	3-2
	I, C	EE 3631	Antenna Engineering and Propagation Theory .....	3-2
	C	EE 4631	Antenna Engineering.....	3-2
	II	EE 3822	Digital Computer Systems .....	3-3
Ninth	I	EE 3264	Advanced Theory of Semiconductor Devices .....	4-0
	II	EE 4414	Statistical Control Theory .....	3-0
	I	PH 4790	Theory of Solid State and Quantum Devices	3-0
	II	EE 4417	Optimal Control .....	3-0
	C	EE 4671	Theory of Propagation....	3-0
	C	EE 3422	Modern Communications	3-2
Eleventh	II, C	EE 4581	Information Theory .....	3-1
	II	EE 3812	Logical Design and Circuitry .....	3-2
	I	*EE 3481	Radar and ECM.....	3-2
	C	*EE 3482	Communications ECM..	3-2
	I, C	*EE 3455	Sonar Systems .....	3-2
	C	EE 3422	Modern Communi- cations .....	3-2
	I	EE 4473	Missile Guidance Systems .....	3-0
	II	EE 4823	Advanced Digital Computer Systems ....	3-1
	II	EE 4414	Statistical Control Theory .....	3-0
	II	EE 4417	Optimal Control .....	3-0
	I, C	EE 4461	Systems Engineering ....	3-1
	II, C	EE 3822	Digital Computers Systems .....	3-3

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#### STAFF COMMUNICATIONS PROGRAM CURRICULUM NUMBER 620 (Group CO)

**OBJECTIVE**—The Staff Communications Curriculum (620) objective is to prepare officers for assignment to major staff and operational Communications billets, ashore and afloat. Completion of this curriculum prepares officers with a sound understanding of Department of Defense and Naval Com-

munications organization and policies, operational communications planning and direction, procedures and equipment utilization. An education in basic electronics, computer techniques and military material management is provided as part of this objective.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree to include undergraduate studies in Mathematics through Calculus and Physics. Additionally, studies in any of the scientific and engineering fields would be particularly helpful.

**DESCRIPTION**—Officers ordered for instruction to this program will matriculate in a three-quarter curriculum consisting of both technical and non-technical courses. Since officers successfully completing this curriculum are awarded Diplomas of Completion, academic entrance prerequisites are somewhat less stringent than those required in the degree-awarding curricula of the Electronics and Communications Engineering Programs. The standard three-quarter curriculum followed by most entering students is listed below. Minor variations in the technical courses are possible dependent upon individual scholastic background.

#### STAFF COMMUNICATIONS PROGRAM (Group CO)

##### First Quarter

EE 2221	Electronics Fundamentals I.....	3- 2
MA 1110	Review of Elementary Calculus.....	5- 0
MN 2970	Material Management .....	4- 0
CO 2111	Communications Organization and Planning .....	4- 0
		<hr/> 16- 2

##### Second Quarter

EE 2223	Intermediate Electronics .....	3- 3
PS 2111	Introduction to Probability and Statistics I.	4- 0
CO 2114	Communications Equipment and Systems Application I .....	4- 0
CO 2112	Communications Administration and Procedures I .....	4- 0
		<hr/> 15- 3

##### Third Quarter

EE 2224	Communications Electronics .....	4- 3
EE 2832	Computer Systems Technology.....	3- 2
CO 2115	Communications Equipment and Systems Application II .....	4- 2
CO 2113	Communications Administration and Procedures II .....	4- 0
		<hr/> 15- 7

## ENGINEERING SCIENCE PROGRAMS

### CURRICULUM NUMBER 460

MARTIN FULLER COMBS, Lieutenant Commander, U.S. Navy; Curricular Officer; B.S., Vanderbilt Univ., 1950; M.S., Physics, Naval Postgraduate School, 1965.

HUGO MURUA MARTINEZ, Academic Associate; B.A., Univ. of California at Berkeley, 1952; M.S., Stanford Univ., 1961; Ph.D., Univ. of Chicago, 1963.

**OBJECTIVE**—To refresh officers in mathematics and the physical sciences for 24 weeks in order to prepare them for admission to an advanced technical curriculum.

To provide a program of 36 weeks duration designed to update and build on undergraduate education in mathematics and the physical sciences.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree; and have completed successfully at least one college mathematics course in algebra, trigonometry, or mathematical analysis. The specific curriculum within the Engineering Science Programs in which a student is enrolled depends primarily on his undergraduate record. Consideration is given to undergraduate courses taken, grades earned, undergraduate institution at which these grades were earned, and length of time away from formal education.

**DESCRIPTION**—For those officers who desire an education in one of the advanced technical curricula but who are deficient in mathematics or the physical sciences, a 24-week refresher period in the Engineering Science Programs is considered the best means of determining the extent of the deficiency and of eliminating it. Elective options are available in each of the curricula to best fit the student's background and the requirements of the advanced technical curriculum for which he is preparing. Transfers to other technical curricula will normally be made after two quarters and will be based upon length of availability of the student for duty under instruction, academic performance, and quota limitations in the technical curricula.

The 36-week program provides intensive education in mathematics, classical and modern physics, chemistry, electronics, probability and statistics, operations research, oceanography and other selected subjects to supplement and fortify prior undergraduate education. It prepares naval officers for advanced functional training, such as Naval Tactical Data Systems, Polaris and other missile systems, test pilot schools, and enables them to communicate with scientists, technicians and engineers with whom they may work in their future naval careers.

### HIGH ACADEMIC BACKGROUND (Group SA)

#### First Quarter

MA 1100	Calculus Review .....	4-0
PH 1011	General Physics I .....	4-0
PS 2111	Introduction to Probability and Statistics I .....	4-0
*OC 2110	Introduction to Oceanography .....	3-0
		15-0

#### Second Quarter

MA 2121	Differential Equations and Infinite Series .....	4-0
PH 1012	General Physics II .....	4-0
OA 2201	Elements of Operations Research/ Systems Analysis .....	4-0
CH 2001	General Principles of Chemistry .....	3-2
		15-2

#### Third Quarter

MA 2161	Introduction to Mathematical Physics .....	3-0
PH 2017	General Physics III .....	4-2
EE 2221	Electronic Fundamentals I .....	3-2
MA 2232	Numerical Methods and FORTRAN Programming .....	4-0
		14-4

### AVERAGE ACADEMIC BACKGROUND (Group SB)

#### First Quarter

MA 1105	Calculus and Analytic Geometry I .....	5-0
PH 1011	General Physics I .....	4-0
PS 2111	Introduction to Probability and Statistics I .....	4-0
*OC 2110	Introduction to Oceanography .....	3-0
		16-0

#### Second Quarter

MA 1106	Calculus and Analytic Geometry II .....	5-0
PH 1012	General Physics II .....	4-0
OA 2201	Elements of Operations Research/ Systems Analysis .....	4-0
CH 2001	General Principles of Chemistry .....	3-2
		16-2

#### Third Quarter

MA 1107	Calculus and Analytic Geometry III .....	3-0
PH 2017	General Physics III .....	4-2
EE 2221	Electronics Fundamentals I .....	3-2
MA 2232	Numerical Methods and FORTRAN Programming .....	4-0
		14-4

\* GV 1368 American Life and Institutions (3-0) replaces OC 2110 for Allied Officers.

### FAIR ACADEMIC BACKGROUND (UPPER) (Group SC)

#### First Quarter

MA 1021	College Algebra and Trigonometry .....	4-0
PH 1005	General Physics I .....	3-2
CH 1001	Introductory General Chemistry .....	4-2
*OC 2110	Introduction to Oceanography .....	3-0
		14-4

#### Second Quarter

MA 1105	Calculus and Analytic Geometry I .....	5-0
PH 1006	General Physics II .....	3-2
PS 2311	Elementary Probability and Statistics .....	3-0
CS 2100	Introduction to Computers and Programming .....	4-0
		15-2

*Third Quarter*

MA 1106	Calculus and Analytic Geometry II.....	5- 0
PH 1007	General Physics III .....	4- 2
OA 2201	Elements of Operations Research/ Systems Analysis .....	4- 0
EE 2221	Electronic Fundamentals I .....	3- 2
		<hr/> 16- 4

**FAIR ACADEMIC BACKGROUND (Lower)**  
**(Group SD)**

*First Quarter*

MA 1010	Intermediate Algebra .....	4- 0
MA 1030	Elementary Sets with Applications.....	3- 0
PH 1005	General Physics I.....	3- 2
CH 1001	Introductory General Chemistry .....	4- 2
		<hr/> 14- 4

*Second Quarter*

MA 1021	College Algebra and Trigonometry.....	4- 0
CS 2100	Introduction to Computers and Programming .....	4- 0
PH 1006	General Physics II .....	3- 2
*OC 2110	Introduction to Oceanography .....	3- 0
		<hr/> 14- 2

*Third Quarter*

MA 1105	Calculus and Analytic Geometry I.....	5- 0
PS 2311	Elementary Probability and Statistics.....	3- 0
PH 1007	General Physics III .....	4- 2
EE 2221	Electronic Fundamentals I .....	3- 2
		<hr/> 15- 4

\* GV 1368 American Life and Institutions (3-0) replaces  
OC 2110 for Allied Officers.



*Swimming Pool open all year*



## ENVIRONMENTAL SCIENCES PROGRAMS CURRICULA NUMBERS 372 AND 440

RICHARD SHERRY DOWNEY, Commander, U.S. Navy; Curricular Officer; B.S., Meteorology, Naval Postgraduate School, 1961.

CHARLES LUTHER TAYLOR, Academic Associate; B.S., Pennsylvania State Univ., 1942; M.S., 1947.

JOHN DAVID PLOETZ, Commander, U.S. Navy; Assistant Curricular Officer; B.A.S., Univ. of California at Los Angeles, 1946.

**OBJECTIVE**—To provide advanced education in meteorology and oceanography to meet the Navy's operational and technical requirements in the environmental sciences.

**QUALIFICATIONS FOR ADMISSION**—The General Meteorology Curriculum requires education in mathematics prerequisite to the calculus and an introductory course in general physics. The Advanced Meteorology and Oceanography Curricula require mathematics through differential and integral calculus and at least one year of college physics. The Oceanography Curriculum additionally requires a year of college chemistry.

**DESCRIPTION**—The Bachelor of Science in Meteorology degree is awarded upon successful completion of the General Meteorology Curriculum if the general requirements for the Bachelor of Science degree are also fulfilled; the Master of Science in Meteorology and Master of Science in Oceanography are attainable through the Advanced Meteorology and Oceanography Curricula respectively. All three curricula in the Environmental Sciences Programs are of seven quarters duration with matriculation scheduled for the quarters beginning in September and March.

The Meteorology Curricula consist basically of core sequences of courses in dynamic, synoptic, and physical meteorology. Sufficient practical laboratory work and oceanographic courses are included to prepare the officers to become qualified operational meteorologists with a working knowledge of oceanography. Numerical methods and computer meteorology are emphasized, and the Advanced Meteorology Curriculum prepares officers to conduct independent scientific research.

The Oceanographic Curriculum provides a broad education in oceanography including courses in biological, geological, and chemical oceanography. The core of the curriculum is, however, the sequence of courses in physical and dynamical oceanography. Emphasis is placed upon the application of oceanography to naval operations, and practical experience in the use of oceanographic instruments and the collection of scientific observations at sea is included. As in meteorology, computer technology is also emphasized, and officers are prepared to conduct independent research through advanced study.

## ADVANCED METEOROLOGY CURRICULUM CURRICULUM NUMBER 372 (MM)

### First Quarter

MA 1100	Calculus Review .....	4-0
MA 2045	Introduction to Linear Algebra.....	3-0
OC 2110	Introduction to Oceanography .....	3-0
MR 2200	Introduction to Meteorology .....	3-0
MR 2410	Meteorological Instruments .....	3-2
		16-2

### Second Quarter

MA 3181	Vector Analysis .....	3-0
MA 2121	Differential Equations and Infinite Series .....	4-0
MR 1105	Weather Codes-Observations-Plotting.....	0-3
MR 3510	Statistical Climatology .....	4-2
MR 3411	Meteorological Thermodynamics .....	4-0
		15-5

### Third Quarter

MA 3132	Partial Differential Equations and Integral Transforms .....	4-0
MR 2220	Weather Map Analysis .....	4-0
MR 2225	Weather Map Analysis Laboratory .....	0-6
MR 4321	Dynamic Meteorology I .....	4-0
MR 4412	Heat Transfer Processes .....	4-0
		16-6

### Fourth Quarter

MA 2232	Numerical Methods and FORTRAN Programming .....	4-0
MR 3230	Tropospheric and Stratospheric Meteorology .....	4-0
MR 3235	Tropospheric and Stratospheric Meteorology Laboratory .....	0-9
MR 4322	Dynamic Meteorology II .....	4-0
		12-9

### Fifth Quarter

MA 3243	Numerical Methods for Partial Differential Equations .....	4-1
MR 3250	Tropical and Southern Hemisphere Meteorology .....	3-0
MR 3255	Tropical and Southern Hemisphere Meteorology Laboratory .....	0-6
MR 4323	Numerical Weather Prediction .....	4-2
OC 3260	Sound in the Ocean.....	3-0
		14-9

### Sixth Quarter

MR 4422	Upper Atmosphere Physics .....	3-0
MR 3260	Prognostic Charts and Extended Forecasting .....	3-0
MR 3265	Prognostic Charts and Extended Forecasting Laboratory .....	0-6
	Thesis .....	0-8
		6-14

### Seventh Quarter

MR 2279	Operational Meteorology .....	1-6
OC 3611	Ocean Wave and Surf Forecasting.....	2-0
OC 3615	Ocean Wave and Surf Forecasting Laboratory .....	0-6
MR 4900	Seminar in Meteorology .....	2-0
	Thesis .....	0-8
		5-20

**GENERAL METEOROLOGY CURRICULUM  
CURRICULUM NUMBER 372 (MA)**

*First Quarter*

MA 1115	Calculus I .....	5- 0
OC 2110	Introduction to Oceanography .....	3- 0
MR 2200	Introduction to Meteorology .....	3- 0
MR 2410	Meteorological Instruments .....	3- 2
		14- 2

*Second Quarter*

MA 1116	Calculus II .....	5- 0
MA 2181	Introduction to Vectors .....	3- 0
MR 1105	Weather Codes-Observations-Plotting.....	0- 3
MR 2510	Climatology .....	4- 2
MR 2411	Introduction to Thermodynamics of Meteorology .....	4- 0
		16- 5

*Third Quarter*

CS 2110	Introduction to Computer Processes.....	3- 0
MR 2220	Weather Map Analysis .....	4- 0
MR 2225	Weather Map Analysis Laboratory.....	0- 6
MR 3301	Fundamentals of Dynamic Meteorology I .....	4- 0
		11- 6

*Fourth Quarter*

CS 3111	Computer Organization and Programming .....	4- 0
MR 3230	Tropospheric and Stratospheric Meteorology .....	4- 0
MR 3235	Tropospheric and Stratospheric Meteorology Laboratory .....	0- 9
MR 3302	Fundamentals of Dynamic Meteorology II .....	4- 0
		12- 9

*Fifth Quarter*

MR 3403	Introduction to Energy-Transfer Processes .....	4- 0
MR 3250	Tropical and Southern Hemisphere Meteorology .....	3- 0
MR 3255	Tropical and Southern Hemisphere Meteorology Laboratory .....	0- 6
MR 3303	Computer Meteorology .....	3- 0
OC 3260	Sound in the Ocean.....	3- 0
		13- 6

*Sixth Quarter*

MR 3260	Prognostic Charts and Extended Forecasting .....	3- 0
MR 3265	Prognostic Charts and Extended Forecasting Laboratory .....	0- 6
OC 3616	Oceanographic Forecasting .....	3- 0
OC 3621	Oceanographic Forecasting Laboratory .....	0- 4
	Research Problem .....	0- 6
		6-16

*Seventh Quarter*

MR 2279	Operational Meteorology .....	1- 6
OC 3611	Ocean Wave and Surf Forecasting.....	2- 0
OC 3615	Ocean Wave and Surf Forecasting Laboratory .....	0- 6
MR 3900	Seminar in Meteorology .....	2- 0
	Research Problem .....	0- 6
		5-18

**OCEANOGRAPHY CURRICULUM  
CURRICULUM NUMBER 440 (MO)**

*First Quarter*

MA 1100	Calculus Review .....	4- 0
MA 2045	Introduction to Linear Algebra .....	3- 0
OC 2110	Introduction to Oceanography .....	3- 0
MR 2200	Introduction to Meteorology .....	3- 0
MR 2205	Meteorology for Oceanographers .....	0- 4
		13- 4

*Second Quarter*

MA 3181	Vector Analysis .....	3- 0
MA 2121	Differential Equations and Infinite Series	4- 0
MR 3510	Statistical Climatology .....	4- 2
OC 3520	Chemical Oceanography .....	3- 2
		14- 4

*Third Quarter*

MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
OC 3320	Geological Oceanography .....	3- 3
OC 3420	Biological Oceanography .....	3- 3
OC 3220	Descriptive Oceanography .....	3- 0
		13- 6

*Fourth Quarter*

MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
OC 4251	Dynamical Oceanography I .....	4- 0
OC 4211	Waves and Tides .....	4- 0
OC 3700	Oceanographic Instrumentation and Observations .....	3- 0
OC 3710	Field Experience in Oceanography.....	0- 4
		15- 4

*Fifth Quarter*

MA 3243	Numerical Methods for Partial Differential Equations .....	4- 1
OC 4252	Dynamical Oceanography II .....	4- 0
OC 4260	Sound in the Ocean .....	3- 0
OC 3601	Ocean Wave Forecasting .....	3- 0
OC 3605	Ocean Wave Forecasting Laboratory.....	0- 6
		14- 7

*Sixth Quarter*

OC 4253	Dynamical Oceanography III .....	3- 0
OC 4213	Coastal Oceanography .....	4- 1
OC 3616	Oceanographic Forecasting .....	3- 0
OC 3621	Oceanographic Forecasting Laboratory ...	0- 4
	Thesis .....	0- 8
		10-13

*Seventh Quarter*

OC 4612	Polar Oceanography .....	3- 0
OC 4900	Seminar in Oceanography .....	3- 0
	Elective in Oceanography.....	3-0 or 1- 4
	Thesis .....	0- 8
		9-8 or 7-12

\* Electives.

OC 4340	Marine Geophysics .....	3- 0
OC 4421	Marine Ecology .....	1- 4

## NAVAL ENGINEERING PROGRAMS CURRICULUM NUMBER 570

EUGENE MARION HENRY, Commander, U.S. Navy; Curricular Officer; B.S., Naval Academy, 1946; M.S., Naval Postgraduate School, 1960.

PAUL FRANCIS PUCCI, Academic Associate; B.S. in M.E., Purdue Univ., 1949; M.S. in M.E., 1950; Ph.D., Stanford Univ., 1955.

ANTONIO NEVAREZ, Lieutenant Commander, U.S. Navy; Assistant Curricular Officer; B.S., Naval Academy, 1953; B.S. in Electrical Engineering, Naval Postgraduate School, 1959.

**OBJECTIVE**—To provide selected officers with advanced education in ship engineering, primarily in mechanical and electrical engineering, to meet the requirements of the Navy for officers with technical and administrative competence related to shipboard engineering plants, including machinery systems, and structures. The specific areas of study are designed to include, within the various curricula, the fundamental and advanced theories of mathematics, thermodynamics, statics, dynamics, electrical power, circuits and feedback control, engineering materials, structures, atomic and nuclear physics, and nuclear power.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with a grade average of B or better in mathematics, physical sciences, and engineering is required. Completion of mathematics through differential and integral calculus, and one year of engineering physics is considered to be minimal preparation. Courses in mechanics, thermodynamics, and electrical engineering are very desirable.

**DESCRIPTION**—All students initially enter a common Naval Engineering (General) Curriculum. After completion of two quarters, students are selected to pursue studies in a specialty of either Mechanical or Electrical Engineering. Upon completion of the first year of study, a limited number of students in each specialty are further selected to follow an advanced three year curriculum in their specialty (Mechanical or Electrical Engineering).

The criteria for selection are academic performance, assigned quotas, tour availability, and student preference.

The Curricula are:

Naval Engineering (Mechanical).....2 year curriculum  
Naval Engineering (Electrical).....2 year curriculum  
Mechanical Engineering (Advanced)....3 year curriculum  
Electrical Engineering (Advanced).....3 year curriculum

For properly qualified students, the two year curricula lead to the award of a designated Bachelor of Science degree and the three year curricula lead to the award of a designated Master of Science degree.

### NAVAL ENGINEERING (GENERAL) (Group NG)

**OBJECTIVE**—This is a two quarter, common-core program followed by all officer students entering the Naval Engineering Curricula. The objective is to educate officers in the basic sciences and engineering principles as a foundation

for more advanced studies in either an electrical or mechanical engineering specialty.

#### First Quarter

ME 2501	Mechanics I .....	4- 0
EE 2101	Principles of Electrical Engineering.....	3- 2
MA 1100	Calculus Review .....	4- 0
MA 2045	Introduction to Linear Algebra.....	3- 0
		14- 2

#### Second Quarter

ME 2502	Mechanics II .....	3- 0
EE 2102	Circuit Analysis .....	4- 2
CH 2001	General Principles of Chemistry.....	3- 2
MA 2121	Differential Equations and Infinite Series .....	4- 0
		14- 4

### NAVAL ENGINEERING (MECHANICAL) (Group NH)

**OBJECTIVE**—To support the aim of the basic objective to the extent practicable within a two year period by providing officer students with a sound science-engineering basis for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Mechanical Engineering aspects.

#### First and Second Quarters

Same as Naval Engineering (General)

#### Third Quarter

ME 2601	Mechanics of Solids I .....	3- 2
EE 2332	Electric Machines .....	3- 3
ME 2201	Mechanics of Fluids I.....	4- 2
ME 2101	Engineering Thermodynamics .....	3- 2
		13- 9

#### Fourth Quarter

MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
EE 2201	General Electronics .....	4- 2
MS 2201	Engineering Materials I .....	3- 2
ME 2102	Mechanical Engineering Thermodynamics .....	4- 0
		15- 4

#### Fifth Quarter

ME 3621	Mechanics of Solids II.....	4- 0
ME 2220	Heat Transfer and Gasdynamics.....	4- 2
ME 3521	Mechanical Vibrations .....	3- 2
MS 2202	Engineering Materials II .....	3- 2
		14- 6

#### Sixth Quarter

ME 2721	Machine Design I .....	3- 2
OA 3201	Fundamentals of Operations Analysis.....	4- 0
PH 2810	Survey of Nuclear Physics.....	4- 0
ME 3310	Marine Power Systems Analysis.....	2- 4
ME 2410	Mechanical Engineering Laboratory I.....	1- 3
		14- 9

#### Seventh Quarter

ME 2722	Machine Design II .....	2- 4
MN 2970	Material Management .....	4- 0
ME 3340	Nuclear Power Systems .....	4- 0
ME 2420	Mechanical Engineering Laboratory II.....	2- 3
GV 1368	American Life and Institutions.....	3- 0
		(Allied Officers only in place of MN 2970)
		12- 7



### MECHANICAL ENGINEERING (ADVANCED) (Group NA)

**OBJECTIVE**—To further the aim of the basic objective by providing officer students with a broad background of science-engineering studies in a three-year program designed to prepare them for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Mechanical Engineering aspects.

First, second, third, and fourth quarters same as Naval Engineering (Mechanical).

#### Fifth Quarter

ME 3611	Mechanics of Solids II.....	4- 0
ME 3202	Mechanics of Fluids II.....	3- 0
MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
EE 3498	Dynamic Systems Analysis .....	3- 3
ME 2410	Mechanical Engineering Laboratory I.....	1- 3
		15- 6

#### Sixth Quarter

ME 4612	Mechanics of Solids III.....	4- 0
ME 4203	Mechanics of Fluids III.....	4- 0
ME 4511	Vibration Theory .....	3- 2
PH 2810	Survey of Nuclear Physics.....	4- 0
		15- 2

#### Seventh Quarter

ME 3711	Machine Design I .....	3- 2
ME 3210	Heat Transfer .....	4- 2
ME 3320	Marine Power Systems Analysis.....	2- 4
ME 3430	Mechanical Engineering Laboratory II.....	2- 3
		11-11

**Eighth Quarter**—Six weeks of classroom work followed by a six weeks tour at selected industrial or research activities.

MN 2970	Material Management .....	4- 0
GV 1368	American Life and Institutions.....	3- 0
	(Allied Officers only in place of MN 2970)	
MS 2202	Engineering Materials II .....	3- 2
		7- 2

#### Ninth Quarter

ME 4351	Nuclear Engineering I.....	4- 0
ME 3712	Machine Design II .....	3- 4
ME 4512	Advanced Dynamics .....	4- 0
MN 2900	Management of Human Resources.....	4- 0
		15- 4

#### Tenth Quarter

ME 4352	Nuclear Engineering II .....	3- 3
OA 3201	Fundamentals of Operations Analysis.....	4- 0
	Thesis .....	0- 8
		7-11

#### Eleventh Quarter

ME 4120	Direct Energy Conversion .....	3- 0
OA 3202	Methods of Operations Analysis/ Systems Analysis .....	4- 0
	Thesis .....	0- 8
		7- 8

### NAVAL ENGINEERING (ELECTRICAL) (Group NL)

**OBJECTIVE**—To support the aim of the basic objective to the extent practicable within a two year period by providing officer students with a sound science-engineering basis for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Electrical Engineering aspects.

#### First and Second Quarters

Same as Naval Engineering (General)

#### Third Quarter

MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
EE 2211	Electronic Engineering Fundamentals I.....	4- 2
ME 2110	Applied Thermodynamics .....	4- 2
MA 2172	Complex Variables .....	3- 0
		15- 4

#### Fourth Quarter

MS 2228	Introduction to Engineering Materials.....	3- 2
EE 2212	Electronic Engineering Fundamentals II.....	4- 3
PH 2810	Survey of Nuclear Physics.....	4- 0
EE 3103	Linear Systems Analysis .....	3- 3
		14- 8

#### Fifth Quarter

ME 2601	Mechanics of Solids I.....	3- 2
EE 2611	Electromagnetic Fields .....	3- 0
EE 2311	Principles of Energy Conversion.....	3- 2
EE 3411	Control Systems .....	3- 3
EE 2811	Digital Machines .....	2- 0
		14- 7

#### Sixth Quarter

EE 3114	Communication Theory I.....	4- 0
ME 3330	Nuclear Power Fundamentals .....	4- 0
EE 2312	Electromagnetic Machines .....	3- 4
	Elective .....	3- 3
		14- 7

#### Seventh Quarter

EE 2213	Electronic Communication Circuits .....	4- 3
OA 3201	Fundamentals of Operations Analysis.....	4- 0
MN 2970	Material Management .....	4- 0
	Elective .....	3- 3
GV 1368	American Life and Institutions.....	3- 0
	(Allied Officers only in place of MN 2970)	
		15- 6

#### Typical Electives, B.S. Program

EE 3261	Nonlinear Magnetic Devices .....	3- 3
EE 3412	Nonlinear and Sampled Systems.....	3- 3
EE 2214	Electronic Pulse and Digital Circuits.....	4- 3
EE 3313	Marine Electrical Analysis and Design.....	3- 2
EE 2612	Transmission of Electromagnetic Energy..	3- 1
EE 2711	Electrical and Electronic Measurement.....	3- 3

### ELECTRICAL ENGINEERING (ADVANCED) (Group NE)

OBJECTIVE—To further the aim of the basic objective by providing officer students with a broad background of science-engineering studies in a three-year program designed to prepare them for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Electrical Engineering aspects.

First, second, third, and fourth quarters same as Naval Engineering (Electrical).

#### Fifth Quarter

ME 2601	Mechanics of Solids I.....	3- 2
EE 3411	Control Systems .....	3- 3
EE 2311	Principles of Energy Conversion.....	3- 2
MA 2161	Introduction to Mathematical Physics.....	3- 0
EE 2811	Digital Machines .....	2- 0
		<hr/> 14- 7

#### Sixth Quarter

EE 2214	Electronic Pulse and Digital Circuits.....	4- 3
EE 3114	Communication Theory I .....	4- 0
EE 2312	Electromagnetic Machines .....	3- 4
EE 3621	Electromagnetics I .....	3- 1
		<hr/> 14- 8

#### Seventh Quarter

EE 2213	Electronic Communications Circuits .....	4- 3
EE 3412	Nonlinear and Sampled Systems.....	3- 3
OA 3201	Fundamentals of Operations Analysis.....	4- 0
EE 3622	Electromagnetics II .....	3- 0
		<hr/> 14- 6

Eighth Quarter—Six weeks of classroom work followed by a six weeks tour at selected industrial or research activities.

MN 2970	Material Management .....	4- 0
EE 4121	Advanced Network Theory I.....	3- 2
GV 1368	American Life and Institutions.....	3- 0
	(Allied Officers only in place of MN 2970)	
		<hr/> 7- 2

#### Ninth Quarter

MN 2900	Management of Human Resources.....	4- 0
	Elective .....	3- 2
	Elective .....	3- 2
	Elective .....	3- 2
EE 0951	Thesis Seminar .....	0- 1
		<hr/> 13- 7

#### Tenth Quarter

	Elective .....	3- 2
ME 3330	Nuclear Power Fundamentals .....	4- 0
	Thesis .....	0- 4
	Thesis .....	0- 4
EE 0951	Thesis Seminar .....	0- 1
		<hr/> 7-11

#### Eleventh Quarter

EE 3313	Marine Electrical Analysis and Design.....	3- 2
OA 3202	Methods of Operations Analysis/ Systems Analysis .....	4- 0
	Thesis .....	0- 4
	Thesis .....	0- 4
EE 0951	Thesis Seminar .....	0- 1
		<hr/> 7-11

#### Typical Electives. M.S. Program

EE 4414	Statistical Control Theory .....	3- 0
EE 4417	Optimal Control .....	3- 0
EE 4491	Nuclear Reactor Control Systems.....	3- 0
EE 4122	Advanced Network Theory II.....	3- 2
EE 4123	Advanced Network Theory III.....	3- 2
EE 4571	Statistical Communication Theory .....	3- 2
EE 3263	Solid State Circuit Design.....	3- 3
EE 4125	Operational Methods in Linear Systems....	3- 0
EE 3261	Nonlinear Magnetic Devices .....	3- 3

### MATHEMATICS (MS) CURRICULUM CURRICULUM NUMBER 430 (Group NMX)

OBJECTIVE—To provide advanced studies in mathematics for selected Naval Academy graduates in order to help meet the Navy's need for officers with advanced education in this field.

DESCRIPTION—The curriculum is of three quarters' duration; classes commence in July and terminate in March. Students ordered to this curriculum report direct from the Naval Academy upon their graduation. Candidates for this program must have satisfied the Naval Academy requirements for a major in mathematics, including courses in Advanced Calculus, Matrices, and Complex Variables. Additionally, candidates must have attained a B average or better for all math courses taken at the Naval Academy. Successful completion of the curriculum leads to the award of a Master of Science degree in Mathematics.

#### First Quarter

MA 4635	Functions of Real Variables I.....	3- 0
PS 3205	Probability .....	3- 0
MA 3565	Modern Algebra I .....	3- 0
MA 3730	Numerical Analysis and Computation.....	3- 0
MA 3660	Boundary Value Problems .....	3- 0
		<hr/> 15- 0

#### Second Quarter

MA 4636	Functions of Real Variables II.....	3- 0
PS 4206	Decision Theory and Classical Statistics..	3- 0
MA 3566	Modern Algebra II .....	3- 0
MA 4872	Topics in Calculus of Variations.....	3- 0
	*Thesis .....	3- 0
		<hr/> 15- 0

#### Third Quarter

MA 4637	Introduction to Functional Analysis.....	3- 0
MA 4622	Principles and Techniques of Applied Mathematics .....	3- 0
	Elective .....	3- 0
	*Thesis .....	6- 0
		<hr/> 15- 0

\* With Department Chairman approval, electives may be substituted for thesis in individual cases.

## NAVAL MANAGEMENT AND OPERATIONS ANALYSIS PROGRAMS

### CURRICULA NUMBERS 817, 367, and 360

CLELL STEWART, Commander U.S. Navy; Curricular Officer; B.S., Naval Postgraduate School, 1965.

DOUGLAS GEORGE WILLIAMS, Academic Associate for Data Processing and Computer Science; M.A. (honors), Univ. of Edinburgh, 1954.

H. ARTHUR HOVERLAND, Academic Associate for Management; B.S., Miami Univ. (Ohio), 1951; M.S., Univ. of Illinois, 1954; Ph.D., Univ. of Michigan, 1963.

WILLIAM PEYTON CUNNINGHAM, Academic Associate for Operations Analysis; B.S., Yale Univ., 1928; Ph.D., 1932.

RICHARD HERBERT KALLIES, Commander, U.S. Navy; Assistant Curricular Officer; Ph.B., Univ. of Wisconsin, 1943.

THOMAS LELAND MEEKS, Commander, U.S. Navy; Assistant Curricular Officer; B.S., Naval Academy, 1952; M.S., Naval Postgraduate School, 1964.

### COMPUTER SCIENCE CURRICULUM CURRICULUM NUMBER 368 (Group CS)

**OBJECTIVE**—To provide officers with an advanced education in computer science to help fulfill the present and future commitments of the Navy in automatic data processing. In the short space of 20 years, the computer has become an indispensable part of almost all Navy activities, both of an operational and supporting nature. Computer Science is a relatively new academic discipline which is concerned with the representation, storage and manipulation of information by techniques and using devices applicable to a wide variety of problems. Graduates will have a deep technical appreciation of the computer technology and the ability to specify, design and manage computer-based systems.

#### Computer Sciences

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with above average grades in mathematics is required. Completion of mathematics through differential and integral calculus is considered to be minimal preparation. Courses in physical sciences or engineering are very desirable.

**DESCRIPTION**—The curriculum is either one year or 7 quarters depending on whether pursuing the Baccalaureate or Master's program with new students enrolled in September and March of each academic year. All students take the same courses for the first three quarters. Then it is determined which students will continue for four additional quarters of the Master's program or complete one additional quarter of the Baccalaureate program. This selection is based on the student's academic record, his preference and availability.

Both curricula involve course work in computer science supported by instruction in mathematics, probability and statistics, and operations analysis. In computer science the

emphasis is on systems design, and generally those aspects of the theory of particular relevance to military applications. The Master's program permits further specialization by way of elective sequences. The student will acquire much practical experience on the excellent equipment of the Computer Facility. Most of the later courses and, it is expected, the thesis, will involve the use of computers.

Successful completion of the Baccalaureate program (four quarters) leads to the award of the Bachelor of Science degree.

Successful completion of the Master's program (seven quarters) leads to the award of the degree Master of Science in Computer Science.

#### *First Quarter*

MA 1100	Calculus Review .....	4- 0
MA 2025	Logic, Sets and Finite Mathematics.....	3- 0
PS 2325	Introduction to Probability Theory.....	3- 1
CS 2110	Introduction to Computer Processes.....	3- 0
		13- 1

#### *Second Quarter*

MA 2121	Differential Equations and Infinite Series	4- 0
MA 2045	Introduction to Linear Algebra.....	3- 0
PS 3326	Probability and Statistics .....	3- 1
CS 3111	Computer Organization and Programming	4- 0
		14- 1

#### *Third Quarter*

PS 3327	Applied Statistics .....	3- 1
CS 4112	Systems Programming I .....	4- 0
CS 3300	Information Structures .....	3- 0
CS 3200	Logical Design of Digital Computers.....	4- 0
		14- 1

#### *Fourth Quarter (Baccalaureate Program)*

MN 4182	Data Processing Management .....	4- 0
CS 3500	Military Applications of Computers.....	4- 0
OA 3203	Survey of Operations Analysis/ Systems Analysis .....	4- 0
MN 4183	Business Data Processing.....	4- 0
		16- 0

#### *Fourth Quarter (Master's Program)*

MN 4182	Data Processing Management .....	4- 0
CS 3500	Military Applications of Computers.....	4- 0
MA 3172	Complex Variables .....	4- 0
MA 3063	Algebraic Foundations of Computer Science .....	3- 0
		15- 0

#### *Fifth Quarter*

MA 3132	Partial Differential Equations and Integral Transforms .....	4- 0
MA 3232	Numerical Analysis I .....	4- 0
CS 3201	Computer Systems Design I .....	4- 0
CS 3204	Data Communications .....	4- 0
		16- 0



*Sixth Quarter*

OA 3205	Optimization Techniques .....	4-0
OA 4910	Selected Topics in Operations Analysis....	4-0
CS 4200	Computer Systems Design, II.....	4-0
	Elective .....	3/4-0
	Thesis .....	2-0
		<hr/> 17/18-0

*Seventh Quarter*

CS 4310	Non-numerical Information Processing.....	4-0
OA 4653	Systems Simulation .....	3-0
	Elective .....	3/4-0
	Thesis .....	6-0
		<hr/> 16/17-0

**ELECTIVE SEQUENCES***Sequence A**Quarter*

6	CS 4113	Systems Programming II .....	4-0
7	CS 4900	Advanced Topics in Computer Science .....	3-0

*Sequence B*

6	MA 3243	Numerical Methods for Partial Differential Equations .....	4-1
7	MA 4237	Advanced Topics in Numerical Analysis .....	4-0

*Sequence C*

6	OA 3704	Stochastic Models I.....	4-0
7	OA 3664	Theory of Pattern Recognition.....	3-0

*Sequence D*

6	MN 3150	Financial Accounting .....	4-0
7	MN 4181	Management Information Systems.....	4-0

*Sequence E*

6	MN 3110	Individual Behavior .....	3-0
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*or*

6	OA 3671	Cybernetics .....	3-0
7	OA 3657	Human Factors in Systems Design.....	4-0

**MANAGEMENT DATA PROCESSING****CURRICULUM****CURRICULUM NUMBER 367****(Group PM)**

**OBJECTIVE**—To provide officers with an advanced education in general management and a sound technical appreciation of computer technology sufficient to allow them to distinguish the capabilities and limitations of digital computers in various applications. A primary goal is to develop the ability and insight to effectively manage computer-based activities or data processing centers.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with overall academic performance of at least C+ is required. Completion of two semesters of college mathematics at, or above, the level of College Algebra, and a C average in all quantitative courses is considered to be minimal preparation. Courses in differential and integral calculus are very desirable.

**DESCRIPTION**—The curriculum is of fifteen months' duration and encompasses five academic quarters. The classwork is primarily in management and data processing, supported by instruction in mathematics, probability and statistics, and operations analysis. The instruction in management is comprehensive and includes most subjects normally required for a graduate degree in that field. In addition the standard curriculum incorporates the Financial Management Elective Sequence of the Naval Management Curriculum. However, substitutions for certain financial management courses will be considered if this emphasis is not appropriate to the needs of the sponsor.

In data processing, the goal is to develop a technical understanding of the capabilities and limitations of digital computers through a study of systems programming and applications.

Successful completion of this program leads to the award of the degree Master of Science in Management Data Processing.

*First Quarter*

MA 2300	Mathematics for Management .....	5-0
MN 3150	Financial Accounting .....	4-0
MN 3141	Micro-Economic Theory .....	4-0
CS 2110	Introduction to Computer Processes.....	3-0
		<hr/> 16-0

*Second Quarter*

PS 3101	Management Statistics I .....	5-0
MN 3161	Managerial Accounting .....	4-0
MN 3130	Macro-Economic Theory .....	4-0
CS 3111	Computer Organization and Programming .....	4-0
		<hr/> 17-0

*Third Quarter*

PS 3102	Management Statistics II .....	4-1
MN 4151	Internal Control and Auditing.....	4-0
CS 3300	Information Structures .....	3-0
CS 4112	Systems Programming I .....	4-0
		<hr/> 15-1

*Fourth Quarter*

OA 3211	Operations Analysis for Management.....	4-0
MN 4161	Controllorship .....	4-0
MN 3171	Resource Management for Defense.....	4-0
MN 4183	Business Data Processing .....	4-0
		<hr/> 16-0

*Fifth Quarter*

OA 3213	Introduction to Logistics and Supply Systems .....	4-0
MN 4181	Management Information Systems .....	4-0
MN 4171	Procurement and Contract Administration .....	4-0
MN 4182	Data Processing Management .....	4-0
		<hr/> 16-0

**MANAGEMENT CURRICULUM  
CURRICULUM NUMBER 817  
(Group MN)**

**OBJECTIVE**—To provide officers with increased education in management which will improve their capabilities for organizing, planning, directing, coordinating and controlling activities in which the resources of men, money, and materials are combined to accomplish Navy objectives.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with overall academic performance of at least C+ is required. Completion of two semesters of college mathematics at, or above, the level of College Algebra, and a C average in all quantitative courses is considered to be minimal preparation. Courses in differential and integral calculus are very desirable.

**DESCRIPTION**—The curriculum is of twelve months' duration at the graduate level. All officers, regardless of designator, are required to participate in the "core" courses. These courses provide the foundation and tools of management and lead into the electives, which permit limited specialization in fields of interest to sponsoring bureaus and agencies.

Classroom instruction is supplemented by a guest lecturer series which affords the officer an opportunity to hear discussions of management topics by senior military officers, business executives, and prominent educators.

Successful completion of this program leads to the award of a Master of Science degree.

*First Quarter*

MA 2300	Mathematics for Management .....	5- 0
MN 3130	Macro-Economic Theory .....	4- 0
MN 3150	Financial Accounting .....	4- 0
MN 3180	Computers and Data Processing.....	3- 0
<i>or</i>		
MN 3110	Individual Behavior .....	3- 0
		16- 0

*Second Quarter*

EN 3310	Research Methods .....	2- 0
PS 3101	Management Statistics I .....	5- 0
MN 3141	Micro-Economics Theory .....	4- 0
MN 3161	Managerial Accounting .....	4- 0
MN 3180	Computers and Data Processing.....	3- 0
<i>or</i>		
MN 3110	Individual Behavior .....	3- 0
		18- 0

*Third Quarter*

OA 3211	Operations Analysis for Management.....	4- 0
MN 3121	Group and Organizational Behavior.....	5- 0
MN 3171	Resource Management for Defense.....	4- 0
	Elective or Thesis.....	0- 0 to 4- 0
		13- 0 to 17- 0

*Fourth Quarter*

MN 4105	Management Policy .....	4- 0
MN 4145	Systems Analysis .....	4- 0
	Electives (or 1 elective and thesis) .....	4- 0 to 8- 0
		12- 0 to 16- 0
<b>TOTAL</b> .....		59- 0 to 67- 0

**ELECTIVE SEQUENCES**

*1—Personnel Management*

*Quarter*

III	MN 4101	Personnel Management and Labor Relations .....	4- 0
IV	MN 4111	Seminar in Behavioral Science.....	4- 0
IV	MN 4121	Seminar in Organization Theory and Management Practice .....	4- 0
			12- 0

*2—Economics*

III	MN 4142	International Economic Studies.....	4- 0
IV	MN 4131	Economic Theory and Macro-Economic Policy .....	4- 0
IV	MN 4141	Economic Theory and Micro-Economic Policy .....	4- 0
			12- 0

*3—Financial Management*

III	MN 4181	Management Information Systems....	4- 0
IV	MN 4151	Internal Control and Auditing.....	4- 0
IV	MN 4161	Controllership .....	4- 0
			12- 0

*4—Material Management*

III	MN 4171	Procurement and Contract Administration .....	4- 0
IV	(MN 4131)	Economic Theory and Macro-Economic Policy) .....	4- 0
IV	(MN 4141)	Economic Theory and Micro-Economic Policy) .....	4- 0
<i>or</i>			
IV	(MN 4151)	Internal Control and Auditing).....	4- 0
IV	(MN 4161)	Controllership) .....	4- 0
			12- 0

*5—Quantitative Analysis*

III	MN 4181	Management Information Systems....	4- 0
IV	MN 4183	Business Data Processing .....	4- 0
IV	MN 4191	Quantitative Decision Techniques....	4- 0
			12- 0

An additional elective course in the Management area is:

IV	MN 4109	Directed Study .....	4- 0
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**OPERATIONS RESEARCH/SYSTEMS ANALYSIS  
CURRICULUM  
CURRICULUM NUMBER 360  
(Group RO)**

**OBJECTIVE**—To develop the analytical ability of officers by providing a sound education in quantitative methods so that they may formulate new concepts and programs in the field of operations research/systems analysis, apply the result of operations research/systems analysis with greater effectiveness, and solve problems which arise in the military service more effectively.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with above average grades in mathematics is required. Completion of mathematics through differential and integral calculus is considered minimal preparation. For Navy Line Officers a one-year course in college physics is also necessary. Students lacking these quantitative prerequisites will be accepted, in certain special cases, where their undergraduate records indicate that they are exceptional students

and there are other possible indicators of success such as Graduate Record Examination scores, corresponding course completions in the quantitative area, and outstanding motivation for the program.

**DESCRIPTION**—Officers are enrolled in the Operations Research/Systems Analysis program twice a year, in March and September. During their first year (four quarters) all students take a common core curriculum, with slight variations designed to meet the particular career needs of Navy Line, Supply Corps, Marine Corps, Army, and Air Force Officers, as appropriate. At the end of three quarters, certain officers are nominated for admission to the Master's program. The criteria for selection are academic standing, student's preference, and availability. These officers continue for a second year of work, a total of eight quarters overall, and are afforded the opportunity to qualify for the degree Master of Science in Operations Research. The Master's curriculum includes a six-week intersessional field trip in which students are individually assigned as working members of an appropriate military or industrial group engaged in operations research/systems analysis of military problems. Additionally, those students in the Master's curriculum must select one of the required elective sequences listed below, and must submit an acceptable thesis.

Those officers not selected for the Master's program continue for one additional quarter in the Baccalaureate curriculum for a total of five quarters overall. This curriculum leads to the degree Bachelor of Science in Operations Research, upon successful completion.

Classroom work is augmented by guest lecturer—seminar series which permit officers to gain first-hand information as to practical applications of operations research/systems analysis principles and techniques.

Officers who possess outstanding quantitative backgrounds may be enrolled in a special Master's degree program of about one year's duration. The specific curriculum in each case is designed to meet the needs of the Service in the operations analysis subspecialty while complementing the officer's educational background.

Officers who demonstrate superior academic ability in the OR/SA curriculum may apply for the Ph.D. program in Operations Research.

#### First Quarter

MA 1101	Review of Calculus Fundamentals.....	5- 0
MA 2042	Linear Algebra .....	4- 0
PS 2301	Probability .....	4- 0
OA 2601	Introduction to Operations Analysis.....	4- 0
OA 0001	Seminar .....	0- 2
		17- 2

#### Second Quarter

MA 2110	Selected Topics from Advanced Calculus	4- 0
MN 3141	Micro-Economics .....	4- 0
PS 3302	Probability and Statistics .....	4- 1
PH 2121	Particle Dynamics (Navy Line Officers) ..	4- 0
<i>or</i>		
OA 3910	Selected Topics in Operations Research/ Systems Analysis (Supply Corps, USMC, USA, and USAF Officers).....	4- 0
OA 0001	Seminar .....	0- 2
		16- 3

#### Third Quarter

PS 3303	Statistics .....	4- 1
OA 2602	War Gaming and Simulation.....	3- 2
OA 3604	Linear Programming .....	4- 0
PH 2221	Wave Phenomena (Navy Line Officers) ....	4- 1
<i>or</i>		
OA 3620	Inventory (Supply Corps, USMC, USA, and USAF Officers) .....	4- 0
OA 0001	Seminar .....	0- 2
		15- 5 or 15- 6

#### Fourth Quarter

OA 3610	Utility Theory and Resource Allocation Models .....	4- 0
OA 3611	Systems Analysis I .....	4- 0
OA 3653	Systems Simulation .....	4- 0
PH 3421	Underwater Acoustics (Navy Line Officers) .....	4- 2
<i>or</i>		
MN 4182	Data Processing Management (Supply Corps, USMC, USA and USAF Officers) .....	4- 0
OA 0001	Seminar .....	0- 2
		16- 2 to 16- 4

#### Fifth Quarter (Baccalaureate Program)

OA 3605	Methods of Operations Research/ Systems Analysis .....	4- 0
OA 3612	Systems Analysis II.....	4- 0
OA 3900	Workshop in Operations Research/ Systems Analysis .....	4- 0
OA 3620	Inventory (Navy Line Officers).....	4- 0
<i>or</i>		
OA 3910	Selected Topics in Operations Research/ Systems Analysis (Supply Corps, USMC, USA, and USAF Officers) .....	4- 0
OA 0001	Seminar .....	0- 2
		16- 2

#### Fifth Quarter (Master's Program)

During the first six weeks of the Quarter, students will have two courses, as listed below, at an accelerated pace:

OA 3612	Systems Analysis II .....	4- 0
OA 3620	Inventory I (Navy Line Officers).....	4- 0
<i>or</i>		
OA 3621	Inventory II (Supply Corps, USMC, USA, and USAF Officers) .....	4- 0
		8- 0

During the last six weeks of the Quarter, student officers will be assigned individually, on a temporary additional duty basis, as working members of appropriate military or Industrial OR/SA Groups. This Intersessional Experience Tour is designed to permit the student to participate in some phase of active Operations Research, and secondarily to assist the student in finding a problem of interest for subsequent thesis study.



*Sixth Quarter (Master's Program)*

OA 3704	Stochastic Models I .....	4- 0
OA 4631	Non-Linear and Dynamic Programming....	4- 0
PH 3921	Conceptual Models of Modern Physics (Navy Line Officers) .....	4- 0
<i>or</i>		
OA 4622	Seminar in Supply Systems (Supply Corps Officers) .....	4- 0
<i>or</i>		
OA 3655	Methods for Combat Development Experi- ments (USMC, USA, and USAF Officers) .....	4- 0
	Elective .....	3- 0 to 4- 0
	Elective (Optional) .....	3- 0 to 4- 0
OA 0001	Seminar .....	0- 2
		15- 2 to 20- 2

*Seventh Quarter (Master's Program)*

OA 4705	Stochastic Models II .....	4- 0
OA 4651	Search Theory and Detection (Navy Line Officers) .....	4- 0
<i>or</i>		
OA 4613	Theory of Systems Analysis (Supply Corps Officers) .....	4- 0
<i>or</i>		
OA 4642	Advanced War Gaming (USMC, USA, and USAF Officers) .....	3- 2
	Elective .....	3- 0 to 4- 0
	Elective (Optional) .....	3- 0 to 4- 0
	Thesis .....	4- 0
OA 0001	Seminar .....	0- 2
		13- 4 to 20- 2

*Eighth Quarter (Master's Program)*

PS 4321	Design of Experiments.....	3- 1
OA 4632	Mathematical Programming .....	4- 0
	Elective .....	3- 0 to 4- 0
	Elective (Optional) .....	3- 0 to 4- 0
	Thesis .....	4- 0
OA 0001	Seminar .....	0- 2
		14- 3 to 19- 3

**ELECTIVE SEQUENCES**

All students in the Master's Program must choose one of the elective sequences below. In addition, optional electives may be chosen from this list. All optional electives must be approved by the Department of Operations Analysis.

**I PROBABILITY AND STATISTICS**

PS 4306	Applied Statistics .....	4- 0
PS 4323	Decision Theory .....	3- 0
PS 4432	Stochastic Processes .....	3- 0

**II ADVANCED SYSTEMS ANALYSIS**

OA 4615	Econometrics .....	3- 0
OA 4613	Theory of Systems Analysis.....	4- 0
OA 4662	Systems Reliability and Life Testing.....	4- 0

**III ADVANCED OPERATIONS ANALYSIS****TECHNIQUES**

OA 4633	Network Flows and Graphs.....	3- 0
OA 4634	Games of Strategy .....	4- 0
OA 4910	Selected Topics in Operations Research/ Systems Analysis .....	3- 0

*or*

MA 3372	Differential Equations for Optimum Control .....	3- 0
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**IV MODERN WARFARE**

OA 3656	Operations Research Problems in Special Warfare .....	4- 0
OA 3657	Human Factors in Systems Design.....	4- 0
OA 4652	Air Warfare .....	3- 0

**V COMPUTERS**

CS 3111	Computer Organization and Programming	4- 0
CS 4112	Systems Programming I .....	4- 0
OA 3664	Theory of Pattern Recognition.....	3- 0

**VI DECISION CRITERIA**

OA 3671	Cybernetics .....	3- 0
OA 4673	Utility Theory .....	3- 0
OA 3672	Decision Criteria .....	3- 0

**VII MATHEMATICAL ECONOMICS**

MN 3130	Macro-Economics .....	4- 0
MN 4941	Mathematical Seminar in Micro- Economics Theory .....	4- 0
MN 4931	Mathematical Seminar in Macro- Economics Theory .....	4- 0



## ORDNANCE ENGINEERING PROGRAMS CURRICULA NUMBERS 521, 530, and 535

WILLIAM ALFRED TEASLEY, JR., Commander, U.S. Navy, Curricular Officer; B.S., Naval Academy, 1946; B.S.E.E., Naval Postgraduate School, 1954; M.S., Massachusetts Institute of Technology, 1955.

OSCAR BRYAN WILSON, JR., Professor of Physics, Academic Associate; B.S., Univ. of Texas, 1944; M.A., Univ. of California at Los Angeles, 1948; Ph.D., 1951.

ALAN J. MARGESON, Lieutenant Commander, U.S. Navy, Assistant Curricular Officer; B.S., Tufts Univ., 1952.

### NUCLEAR ENGINEERING (EFFECTS) CURRICULUM NUMBER 521 (Group RZ)

**OBJECTIVE**—To educate selected officers in various fundamental sciences in order to furnish an advanced technical understanding of the phenomenology of the blast and of the thermal, nuclear, and biological aspects of nuclear weapons effects.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with a grade average of B or better in mathematics, physical sciences, and engineering is required. Completion of mathematics through differential and integral calculus, one year of engineering physics and one year of chemistry is considered to be minimal preparation. Courses in mechanics, thermodynamics, and electrical engineering are very desirable.

**DESCRIPTION**—This curriculum is sponsored by the Defense Atomic Support Agency as a joint-service course for selected officers of the Army, Navy, Air Force, Marine Corps and Coast Guard. It is a two-year curriculum at the graduate level with new students enrolled in July of each year. Successful completion of the two-year curriculum leads to the award of the degree M.S. in Physics. Students who fail to demonstrate their ability at the graduate level will be terminated at the end of the first year and, if otherwise eligible, be awarded the degree B.S. in Physics.

Additional instruction leading to the doctor's degree in nuclear physics may be offered to a limited number of exceptionally well-qualified students. Students may be selected for this additional instruction at any time in the curriculum. Participation in this doctoral program will require the approval of both the Defense Atomic Support Agency and the parent service.

### NUCLEAR ENGINEERING (EFFECTS) CURRICULUM (Group RZ)

#### First Quarter

MA 1100	Calculus Review .....	4- 0
CS 2110	Introduction to Computer Processes.....	3- 0
PH 1051	Review of Mechanics, Thermodynamics, and Optics .....	4- 0
EE 2231	Electronics I (Nuclear).....	3- 3
		<hr/> 14- 3

#### Second Quarter

MA 2121	Differential Equations and Infinite Series .....	4- 0
MA 2161	Introduction to Mathematical Physics.....	3- 0
PH 2151	Mechanics I .....	4- 0
EE 2232	Electronics II (Nuclear).....	3- 3
		<hr/> 14- 3

#### Third Quarter

PH 2251	Waves and Particles .....	4- 2
PH 3152	Mechanics II .....	4- 0
PH 2351	Electromagnetism I .....	3- 0
PH 2551	Thermodynamics .....	3- 0
		<hr/> 14- 2

#### Fourth Quarter

PH 3651	Atomic Physics .....	4- 2
PH 3561	Introductory Statistical Physics.....	4- 0
PH 3352	Electromagnetism II .....	3- 0
PH 3461	Explosive Shock Waves .....	4- 0
PH 0999	Physics Colloquium .....	0- 1
		<hr/> 15- 3

#### Fifth Quarter

PH 3652	Elements of Molecular, Solid State and Nuclear Physics .....	4- 2
PH 4353	Electromagnetism III .....	3- 0
PH 3951	Introduction to Quantum Mechanics.....	3- 0
BI 2800	Fundamentals of Biology.....	4- 0
PH 0999	Physics Colloquium .....	0- 1
		<hr/> 14- 3

#### Sixth Quarter

PH 4851	Nuclear Physics .....	4- 2
PH 4760	Solid State Physics.....	4- 2
BI 3801	Animal Physiology .....	5- 0
PH 0999	Physics Colloquium .....	0- 1
	Thesis Research .....	
		<hr/> 13- 5

#### Seventh Quarter

BI 4802	Radiation Biology .....	5- 0
CH 3401	Chemical Theory .....	4- 0
PH 0999	Physics Colloquium .....	0- 1
	Thesis Research .....	
		<hr/> 9- 1

#### Eighth Quarter

PH 4750	Radiation Effects in Solids.....	3- 2
CH 4501	Radiochemistry .....	2- 4
PH 0999	Physics Colloquium .....	0- 1
	Thesis Research .....	
		<hr/> 5- 7

Upon completion of their second year of studies, officer-students will take a field trip to Field Command, Defense Atomic Support Agency, Sandia Base, Albuquerque, New Mexico, for a specially tailored National Atomic Capabilities Course given by the Atomic Weapons Training Group. This field trip will be taken as temporary duty under instruction en route to their new duty stations under permanent change of station orders issued by their parent services.

### ORDNANCE SYSTEMS ENGINEERING CURRICULUM NUMBER 530

**BASIC OBJECTIVE**—To provide selected officers with an advanced technical education on a broad foundation which encompasses the basic scientific and engineering principles underlying the field of ordnance and an introduction to technical management. The specific areas of study and the level to be attained are formulated for each curriculum to insure a sound basis for technical competence and for such subsequent growth as may be required for the operation, maintenance, design, development, or production of advanced ordnance systems.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with above average grades in mathematics, physical sciences, and engineering is required. Completion of mathematics through differential and integral calculus, one year of engineering physics and one year of chemistry is considered to be minimal preparation. Courses in mathematics, thermodynamics, and electrical engineering are very desirable.

**DESCRIPTION**—Classes convene in September and March. All officers ordered for instruction in Ordnance Systems Engineering initially matriculate in the two-year General Curriculum. At the end of their first two quarters officer-students may be nominated for the three-year Advanced Ordnance Systems Engineering Curricula (Air/Space Physics, Chemistry, Materials or Electronics). This nomination is based on the expressed choice of the individual, his undergraduate performance and his demonstrated ability in the first two quarters. Completion of the advanced curricula leads to the degree of Master of Science. Students who are not selected for an advanced curriculum will continue with the two-year curriculum leading to a degree of Bachelor of Science in Electrical Engineering. Additional Curricula at the basic and advanced level are available to selected officers of the Marine Corps (Group WR), Army (Group WA), and allied countries (Group WS). These curricula are similar to those shown herein with minor modifications to meet the needs of the particular service.

### ORDNANCE SYSTEMS ENGINEERING (GENERAL) CURRICULUM (Group WG)

**OBJECTIVE**—To support the aims of the basic objective to the maximum extent practicable within the two-year period with emphasis on the fundamentals of Ordnance Systems Engineering.

#### First Quarter

MA 1100	Calculus Review .....	4- 0
PH 1051	Review of Mechanics, Thermodynamics, and Optics .....	4- 0
EE 2101	Principles of Electrical Engineering.....	3- 2
CH 2001	General Principles of Chemistry.....	3- 2
		14- 4

#### Second Quarter

MA 2121	Differential Equations and Infinite Series	4- 0
PH 2151	Mechanics I .....	4- 0
EE 2102	Circuit Analysis .....	4- 2
CH 2401	General Thermodynamics .....	3- 0
		15- 2

#### Third Quarter

MA 3172	Complex Variables .....	4- 0
PH 2241	Waves and Particles .....	4- 0
EE 3103	Linear Systems Analysis .....	3- 3
EE 2211	Electronic Engineering Fundamentals I....	4- 2
		15- 5

#### Fourth Quarter

CS 2110	Introduction to Computer Processes.....	3- 0
PH 3641	Atomic Physics .....	4- 2
EE 3114	Communication Theory I .....	4- 0
EE 2212	Electronic Engineering Fundamentals II....	4- 3
		15- 5

#### Fifth Quarter

OA 3201	Fundamentals of Operations Analysis.....	4- 0
EE 2611	Electromagnetic Fields .....	3- 0
EE 2311	Principles of Energy Conversion.....	3- 2
EE 2214	Electronic Pulse and Digital Circuits.....	4- 3
		14- 5

#### Sixth Quarter

MN 3941	Engineering Economics .....	4- 0
EE 2612	Transmission of Electromagnetic Energy..	3- 1
EE 3411	Control Systems .....	3- 3
PH 3421	Underwater Acoustics .....	4- 2
		14- 6

#### Seventh Quarter

OA 3202	Methods of Operations Analysis/Systems Analysis .....	4- 0
EE 2431	Introduction to Radar .....	3- 2
EE 3412	Non-Linear and Sampled Systems.....	3- 3
CH 3705	Reaction Motors .....	3- 0
		13- 5

### ADVANCED ORDNANCE SYSTEMS ENGINEERING (CHEMISTRY) CURRICULUM (Group WC)

**OBJECTIVE**—To further the aims of the basic objective by providing officer-students with a broad background of selected science-engineering studies oriented toward those ordnance systems dependent upon chemical energy for propulsion or explosive applications, with Chemistry as the major field of study and Physics as the principal minor field.

#### First Quarter

Same as Ordnance Systems Engineering (General) Curriculum.

#### Second Quarter

Same as Ordnance Systems Engineering (General) Curriculum.

#### Third Quarter

MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
MA 2161	Introduction to Mathematical Physics.....	3- 0
CH 2402	Introduction to Physical Chemistry.....	3- 3
PH 3152	Mechanics II .....	4- 0
		14- 3

*Fourth Quarter*

CH 2301	Organic Chemistry I .....	4- 2
PH 2251	Waves and Particles .....	4- 2
CH 4401	Chemical Thermodynamics .....	3- 0
CH 2101	Inorganic Analysis .....	3- 3
		<hr/> 14- 7

*Fifth Quarter*

PH 3651	Atomic Physics .....	4- 2
CH 2302	Organic Chemistry II .....	3- 3
CH 2405	Physical Chemical Topics .....	4- 3
CH 0800	Chemistry Seminar .....	0- 1
		<hr/> 11- 9

*Sixth Quarter*

CH 4405	Quantum Chemistry I .....	3- 0
PS 3112	Probability and Statistics .....	4- 0
CH 3201	Chemical Instruments .....	3- 3
CH 2102	Inorganic Chemistry .....	2- 3
CH 0800	Chemistry Seminar .....	0- 1
		<hr/> 12- 7

*Seventh Quarter*

CH 4301	Physical Organic I .....	3- 0
CH 3705	Reaction Motors .....	3- 0
CH 4101	Advanced Inorganic Chemistry .....	3- 3
OA 3202	Methods of Operations Analysis/Systems Analysis .....	4- 0
CH 0800	Chemistry Seminar .....	0- 1
		<hr/> 13- 4

*Eighth Quarter*

PH 3351	Electromagnetism I .....	3- 0
CH 3701	Control Systems .....	3- 3
OA 3203	Survey of Operations Analysis/Systems Analysis .....	4- 0
	*Option .....	4- 0
CH 0800	Chemistry Seminar .....	0- 1
		<hr/> 14- 4

*Ninth Quarter*

PH 3352	Electromagnetism II .....	3- 0
CH 4701	Process Control .....	3- 2
MN 3941	Engineering Economics .....	4- 0
	*Option .....	4- 0
CH 0800	Chemistry Seminar .....	0- 1
	Thesis Research .....	
		<hr/> 14- 3

*Tenth Quarter*

PH 3421	Underwater Acoustics .....	4- 2
	*Option .....	4- 0
CH 0800	Chemistry Seminar .....	0- 1
	Thesis Research .....	
		<hr/> 8- 3

*Eleventh Quarter*

EE 4451	Sonar Systems Engineering .....	3- 2
	*Option .....	4- 0
CH 0800	Chemistry Seminar .....	0- 1
	Thesis Research .....	
		<hr/> 7- 3

## OPTION I—RADIOCHEMISTRY-INORGANIC

CH 4501	Radiochemistry .....	2- 4
	<i>or:</i>	
CH 4800	Special Topics (Radiochemistry) .....	3- 0
	<i>and three of the following:</i>	
MS 3701	Crystallography and X-ray Diffraction Techniques .....	2- 3
CH 4406	Quantum Chemistry II .....	3- 0
CH 4800	Special Topics (Chemical Kinetics) .....	3- 0
CH 4800	Special Topics (Inorganic Chemistry) .....	3- 0

## OPTION II—CHEMISTRY OF CARBON

CH 4302	Physical Organic II .....	3- 0
	<i>and three of the following:</i>	
PH 3561	Introductory Statistical Physics .....	4- 0
CH 4800	Special Topics (Molecular Statistics) .....	3- 0
CH 4800	Special Topics (The Chemistry of High Polymers) .....	3- 0
CH 4800	Special Topics (Natural Products) .....	3- 0
CH 4800	Special Topics (Advanced Organic Chemistry) .....	3- 0
CH 4800	Special Topics (Chemical Kinetics) .....	3- 0

## OPTION III—CHEMICAL ENGINEERING

CH 3717	Unit Operations .....	3- 2
CH 4709	Applied Mathematics of Chemical Engineering .....	3- 2
	<i>and two of the following:</i>	
CH 3709	Explosives Chemistry .....	3- 2
CH 4800	Special Topics (Kinetics) .....	3- 0
CH 4800	Special Topics (Heat Transfer) .....	3- 0
CH 4800	Special Topics (Mass Transfer) .....	3- 0

## OPTION IV—CHEMICAL PHYSICS

CH 4406	Quantum Chemistry II .....	3- 0
	<i>and three of the following:</i>	
PH 3561	Introductory Statistical Physics .....	4- 0
PH 4751	Physics of Solids I .....	3- 0
MS 3701	Crystallography and X-ray Diffraction Techniques .....	2- 3
CH 4800	Special Topics (Chemical Physics) .....	3- 0
CH 4800	Special Topics (Molecular Statistics) .....	3- 0
CH 4800	Special Topics (Chemical Kinetics) .....	3- 0

ADVANCED ORDNANCE SYSTEMS ENGINEERING  
(MATERIALS) CURRICULUM  
(Group WM)

OBJECTIVE—To further the aims of the basic objective by providing officer-students with a broad background of selected science-engineering studies oriented toward those ordnance systems dependent on the properties of materials. The major field of study is Materials Science with Physics as the principal minor field.

*First Quarter*

Same as Ordnance Systems Engineering (General) Curriculum.

*Second Quarter*

Same as Ordnance Systems Engineering (General) Curriculum.

\* In the seventh quarter, students must elect one of the following four options and, as approved by the departmental scholarship committee, will enroll in one course in the elected option in the eighth and subsequent quarters. The maximum number of credit hours of any option course is four.



*Third Quarter*

MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
MA 2161	Introduction to Mathematical Physics.....	3- 0
CH 2402	Introduction to Physical Chemistry.....	3- 3
PH 3152	Mechanics II .....	4- 0
		14- 3

*Fourth Quarter*

PH 2251	Waves and Particles .....	4- 2
MS 2201	Engineering Materials I .....	3- 2
MS 3701	Crystallography and X-ray Diffraction Techniques .....	2- 3
CH 4401	Chemical Thermodynamics .....	3- 0
		12- 7

*Fifth Quarter*

PH 3651	Atomic Physics .....	4- 2
ME 2601	Mechanics of Solids I.....	3- 2
MS 2202	Engineering Materials II .....	3- 2
CH 3705	Reaction Motors .....	3- 0
MS 0300	Materials Science Colloquium .....	0- 1
		13- 7

*Sixth Quarter*

MS 4205	The Structure of Solids.....	3- 4
MS 4312	Materials Systems .....	3- 0
PH 3780	Physics of the Solid State.....	3- 2
PS 3112	Probability and Statistics .....	4- 0
MS 0300	Materials Science Colloquium .....	0- 1
		13- 7

*Seventh Quarter*

MS 4206	The Structure and Mechanical Properties of Crystals .....	3- 0
MS 4215	Phase Transformations .....	3- 4
MN 3941	Engineering Economics .....	4- 0
	*Elective .....	3- 0
MS 0300	Materials Science Colloquium .....	0- 1
		13- 5

*Eighth Quarter*

MS 3304	Corrosion .....	3- 2
OA 3202	Methods of Operations Analysis/Systems Analysis .....	4- 0
EN 2101	Technical Writing .....	3- 0
	*Elective .....	3- 0
MS 0300	Materials Science Colloquium .....	0- 1
	Thesis Research .....	
		13- 3

*Ninth Quarter*

MS 4312	Materials Systems .....	3- 0
OA 3203	Survey of Operations Analysis/Systems Analysis .....	4- 0
MS 0300	Materials Science Colloquium .....	0- 1
	Thesis Research .....	
		7- 1

*Tenth Quarter*

PH 3421	Underwater Acoustics .....	4- 2
MS 4401	Physics of Solids .....	3- 0
MS 0300	Materials Science Colloquium .....	0- 1
	Thesis Research .....	
		7- 3

*Eleventh Quarter*

EE 4451	Sonar Systems Engineering .....	3- 2
CH 4705	Plastics and High Polymers.....	2- 2
MS 3303	Nuclear Reactor Materials .....	3- 0
MS 0300	Materials Science Colloquium .....	0- 1
	Thesis Research .....	
		8- 5

\* Elective in Materials Science depending upon staff availability and interest.

### ADVANCED ORDNANCE SYSTEMS ENGINEERING (AIR/SPACE PHYSICS) CURRICULUM (Group WP)

OBJECTIVE—To further the aims of the basic objective by providing officer-students with a broad background of selected science-engineering studies underlying air and space ordnance systems, with Physics as the major field of study and Electrical Engineering as the principal minor field.

*First Quarter*

Same as Ordnance Systems Engineering (General) Curriculum.

*Second Quarter*

Same as Ordnance Systems Engineering (General) Curriculum.

*Third Quarter*

MA 2161	Introduction to Mathematical Physics.....	3- 0
PH 3152	Mechanics II .....	4- 0
EE 3103	Linear Systems Analysis .....	3- 3
MA 3172	Complex Variables .....	4- 0
		14- 3

*Fourth Quarter*

EE 2211	Electronic Engineering Fundamentals I.....	4- 2
PH 2251	Waves and Particles .....	4- 2
PH 2351	Electromagnetism I .....	3- 0
PS 3112	Probability and Statistics .....	4- 0
		15- 4

*Fifth Quarter*

EE 2212	Electronic Engineering Fundamentals II.....	4- 3
MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
PH 3352	Electromagnetism II .....	3- 0
PH 3651	Atomic Physics .....	4- 2
		15- 5

*Sixth Quarter*

EE 2311	Principles of Energy Conversion.....	3- 2
PH 3951	Introduction to Quantum Mechanics.....	3- 0
PH 4353	Electromagnetism III .....	3- 0
PH 3652	Elements of Molecular, Solid State and Nuclear Physics .....	4- 2
		13- 4

*Seventh Quarter*

EE 3411	Control Systems .....	3- 3
PH 4851	Nuclear Physics .....	4- 2
PH 3561	Introductory Statistical Physics .....	4- 0
CH 3705	Reaction Motors .....	3- 0
PH 0999	Physics Colloquium .....	0- 1
		14- 6

*Eighth Quarter*

EE 3412	Non-Linear and Sampled Systems.....	3- 3
PH 4661	Plasma Physics I .....	3- 0
PH 4751	Physics of Solids I.....	3- 0
PH 4161	Fluid Mechanics I .....	3- 0
PH 0999	Physics Colloquium .....	0- 1
		<hr/> 12- 4

*Ninth Quarter*

PH 4662	Plasma Physics II .....	3- 0
PH 4752	Physics of Solids II.....	3- 2
PH 4162	Fluid Mechanics II .....	3- 0
PH 0999	Physics Colloquium .....	0- 1
Thesis Research		<hr/> 9- 3

*Tenth Quarter*

EE 4433	Radar Systems .....	3- 2
OA 3202	Methods of Operations Analysis/Systems Analysis .....	4- 0
PH 0999	Physics Colloquium .....	0- 1
Thesis Research		<hr/> 7- 3

*Eleventh Quarter*

MA 4362	Introductory Control and Guidance.....	4- 0
OA 3203	Survey of Operations Analysis/Systems Analysis .....	4- 0
PH 0999	Physics Colloquium .....	0- 1
Thesis Research		<hr/> 8- 1

### ADVANCED ORDNANCE SYSTEMS ENGINEERING (ELECTRONICS) CURRICULUM (Group WX)

OBJECTIVE—To provide students with a broad background of science-engineering studies underlying modern ordnance control systems with primary emphasis on electronics control systems and methods of digital computation.

*First Quarter*

Same as Ordnance Systems Engineering (General) Curriculum.

*Second Quarter*

Same as Ordnance Systems Engineering (General) Curriculum.

*Third Quarter*

Same as Ordnance Systems Engineering (General) Curriculum.

*Fourth Quarter*

MA 2232	Numerical Methods and FORTRAN Programming .....	4- 0
PH 3641	Atomic Physics .....	4- 2
EE 3114	Communication Theory I .....	4- 0
EE 2212	Electronic Engineering Fundamentals II..	4- 3
		<hr/> 16- 5

*Fifth Quarter*

EE 3411	Control Systems .....	3- 3
EE 2311	Principles of Energy Conversion.....	3- 2
EE 2214	Electronic Pulse and Digital Circuits.....	4- 3
MA 2161	Introduction to Mathematical Physics.....	3- 0
		<hr/> 13- 8

*Sixth Quarter*

EE 3412	Non-Linear and Sampled Systems.....	3- 3
EE 3621	Electromagnetics .....	3- 1
EE 4121	Advanced Network Theory I.....	3- 2
EE 4125	Operational Methods for Linear Systems..	3- 1
		<hr/> 12- 7

*Seventh Quarter*

EE 3622	Electromagnetics II .....	3- 0
EE 4417	Optimal Control .....	3- 0
EE 4122	Advanced Network Theory II.....	3- 2
EE 2811A	Digital Machines .....	2- 0
PS 3112	Probability and Statistics .....	4- 0
EE 0951	Thesis Seminar .....	0- 1
		<hr/> 15- 3

*Eighth Quarter*

EE 4414	Statistical Control Theory .....	3- 0
EE 4571	Statistical Communication Theory .....	3- 2
EE 3812	Logical Design and Circuitry .....	3- 2
PH 3421	Underwater Acoustics .....	4- 2
EE 0951	Thesis Seminar .....	0- 1
		<hr/> 13- 7

*Ninth Quarter*

EE 3822	Digital Computer Systems .....	3- 3
EE 4433	Radar Systems .....	3- 2
PH 3741	Electronic Properties of Metals and Semiconductors .....	4- 2
EE 0951	Thesis Seminar .....	0- 1
Thesis Research		<hr/> 10- 8

*Tenth Quarter*

EE 4473	Missile Guidance Systems .....	3- 0
OA 3202	Methods of Operations Analysis/Systems Analysis .....	4- 0
EE 0951	Thesis Seminar .....	0- 1
Thesis Research		<hr/> 7- 1

*Eleventh Quarter*

EE 4451	Sonar Systems Engineering .....	3- 2
OA 3203	Survey of Operations Analysis/Systems Analysis .....	4- 0
EE 0951	Thesis Seminar .....	0- 1
Thesis Research		<hr/> 7- 3

### UNDERWATER PHYSICS SYSTEMS CURRICULUM NUMBER 535

**OBJECTIVE**—To provide selected officers, by means of an advanced technical education: (a) A thorough understanding of the problems of underwater physics and their interrelationships with the anti-submarine warfare system and (b) an introduction to technical management.

**QUALIFICATIONS FOR ADMISSION**—A Baccalaureate degree with a grade average of B or better in mathematics, physical sciences, and engineering is required. Completion of mathematics through differential and integral calculus, one year of engineering physics and one year of chemistry is considered to be minimal preparation. Courses in mathematics, thermodynamics, and electrical engineering are very desirable.

**DESCRIPTION**—Class convenes in September. Upon completion of their first two quarters, officer-students are separated (depending on expressed choice of the individual, demonstrated academic potential, and length of availability for postgraduate instruction) into either the two-year curriculum leading to the degree B.S. in Physics, or the three-year curriculum leading to the degree M.S. in Physics.

### UNDERWATER PHYSICS SYSTEMS BASIC CURRICULUM (Group UG)

**OBJECTIVE**—To support the aims of the basic objective to the maximum extent practicable within the two-year period with emphasis on the fundamentals of Underwater Physics.

#### First Quarter

MA 1100	Calculus Review .....	4-0
PH 1051	Review of Mechanics, Thermodynamics, and Optics .....	4-0
EE 2101	Principles of Electrical Engineering.....	3-2
CS 2110	Introduction to Computer Processes.....	3-0
		14-2

#### Second Quarter

MA 2121	Differential Equations and Infinite Series	4-0
PH 2151	Mechanics I .....	4-0
EE 2102	Circuit Analysis .....	4-2
PH 2551	Thermodynamics .....	3-0
		15-2

#### Third Quarter

PH 3152	Mechanics II .....	4-0
MA 2161	Introduction to Mathematical Physics.....	3-0
EE 3103	Linear Systems Analysis .....	3-3
MA 3172	Complex Variables .....	4-0
		14-3

#### Fourth Quarter

EE 2211	Electronic Engineering Fundamentals I....	4-2
PH 2251	Waves and Particles .....	4-2
PH 2351	Electromagnetism I .....	3-0
OA 3201	Fundamentals of Operations Analysis.....	4-0
		15-4

#### Fifth Quarter

EE 2212	Electronic Engineering Fundamentals II..	4-3
PH 3451	Fundamental Acoustics .....	4-0
PH 3352	Electromagnetism II .....	3-0
PH 3651	Atomic Physics .....	4-2
		15-5

#### Sixth Quarter

PH 3452	Underwater Acoustics .....	4-2
MN 3941	Engineering Economics .....	4-0
EE 2213	Electronic Communications Circuits .....	4-3
OC 2110	Introduction to Oceanography .....	3-0
PH 0999	Physics Colloquium .....	0-1
		15-6

#### Seventh Quarter

EE 3455	Sonar Systems .....	3-2
PH 3463	Special Topics in Underwater Acoustics..	3-2
OA 3202	Methods of Operations Analysis/Systems Analysis .....	4-0
EE 3411	Control Systems .....	3-3
PH 0999	Physics Colloquium .....	0-1
		13-8

### ADVANCED UNDERWATER PHYSICS SYSTEMS CURRICULUM (Group UP)

**OBJECTIVE**—To further the aims of the basic objective by providing the officer-student with a broad background in Underwater Physics and the necessary study of Electrical Engineering to meet these goals.

#### First Quarter

Same as Underwater Physics Systems Basic Curriculum.

#### Second Quarter

Same as Underwater Physics Systems Basic Curriculum.

#### Third Quarter

Same as Underwater Physics Systems Basic Curriculum.

#### Fourth Quarter

EE 2211	Electronic Engineering Fundamentals I....	4-2
PH 2251	Waves and Particles .....	4-2
PH 2351	Electromagnetism I .....	3-0
PS 3112	Probability and Statistics .....	4-0
		15-4

#### Fifth Quarter

EE 2212	Electronic Engineering Fundamentals II..	4-3
PH 3451	Fundamental Acoustics .....	4-0
PH 3352	Electromagnetism II .....	3-0
PH 3651	Atomic Physics .....	4-2
		15-5



*Sixth Quarter*

PH 3452	Underwater Acoustics .....	4- 2
PH 4353	Electromagnetism III .....	3- 0
PH 3652	Elements of Molecular, Solid State, and Nuclear Physics .....	4- 2
OC 2110	Introduction to Oceanography .....	3- 0
		<hr/> 14- 4

*Seventh Quarter*

EE 3411	Control Systems .....	3- 3
PH 4453	Propagation of Waves in Fluids.....	4- 0
PH 3561	Introductory Statistical Physics .....	4- 0
OA 3202	Methods of Operations Analysis/Systems Analysis .....	4- 0
		<hr/> 15- 3

*Eighth Quarter*

EE 3412	Non-Linear and Sampled Systems.....	3- 3
PH 4454	Transducer Theory and Design .....	3- 3
PH 4455	Advanced Acoustics Laboratory .....	0- 3
PH 4161	Fluid Mechanics I .....	3- 0
PH 0999	Physics Colloquium .....	0- 1
		<hr/> 9-10

*Ninth Quarter*

PH 4162	Fluid Mechanics II .....	3- 0
EE 4451	Sonar Systems Engineering .....	3- 2
EE 3114	Communication Theory I .....	4- 0
PH 0999	Physics Colloquium .....	0- 1
		Thesis Research
		<hr/> 10- 3

*Tenth Quarter*

EE 4571	Statistical Communication Theory .....	3- 2
OA 3203	Survey of Operations Analysis/Systems Analysis .....	4- 0
PH 0999	Physics Colloquium .....	0- 1
		Thesis Research
		<hr/> 7- 3

*Eleventh Quarter*

PH 4456	Seminar in Applications of Underwater Sound .....	3- 0
EE 4541	Signal Processing .....	3- 1
PH 0499	Acoustic Colloquium .....	0- 1
		Thesis Research
		<hr/> 6- 2

## CURRICULA CONDUCTED AT CIVILIAN UNIVERSITIES

<i>Curriculum</i>	<i>Number</i>	<i>Length</i>	<i>Institution</i>	<i>Curricular-Supervisory Control Authority</i>
Business Administration	810	2 yrs.	Harvard.....	NAVSUPSYSCOMD
			Stanford.....	NAVSUPSYSCOMD
Civil Engineering (Advanced)	470	1-2 yrs.	Georgia Tech.....	NAVFACENGCOMD
Typical Options:			M.I.T.....	NAVFACENGCOMD
			Princeton.....	NAVFACENGCOMD
Structures			Purdue.....	NAVFACENGCOMD
Soil Mechanics			R.P.I.....	NAVFACENGCOMD
Sanitary Engineering			Stanford.....	NAVFACENGCOMD
Waterfront Facilities			Texas A.&M.*.....	NAVFACENGCOMD
Facilities Planning			Tulane.....	NAVFACENGCOMD
Construction Engineering			U. of Cal. (Berkeley).....	NAVFACENGCOMD
Civil Engineering Administration			U. of Colo.....	NAVFACENGCOMD
Deep Ocean Construction Engineering			U. of Ill.....	NAVFACENGCOMD
			U. of Mich.....	NAVFACENGCOMD
			U. of Minn.....	NAVFACENGCOMD
			U. of Wash.....	NAVFACENGCOMD
Electrical Engineering (CEC)	471	15-24 mos.	U. of Mich.....	NAVFACENGCOMD
Engineering Electronics (CEC)	472	12-18 mos.	U. of Mich.....	NAVFACENGCOMD
Financial Management	812	1 yr.	Geo. Wash. U.*.....	NAVCOMP
Hydrographic Engineering (Geodesy)	475	2 yrs.	Ohio St. U.....	OPNAV (OP-09B5)
International Law	672	1 yr.	Geo. Wash. U.*.....	JAG
International Relations	671	1 yr.	American U.*.....	BUPERS
			Harvard.....	BUPERS
Law (Army Judge Advocate Officers Advanced Course)	881	9 mos.	U. of Virginia.....	JAG
Management and Industrial Engineering	540	1 yr.	R.P.I.....	NAVORD/AIRSYSCOMD
Mechanical Engineering (CEC)	473	1 yr.	R.P.I.....	NAVFACENGCOMD
Metallurgical Engineering	640	9 mos.	Carnegie Tech.*.....	NAVSHIPSYSCOMD
Naval Construction and Engineering	510	3 yrs.	M.I.T.....	NAVSHIPSYSCOMD
Nuclear Engineering (Advanced)	520	14 mos.	M.I.T.....	NAVSHIPSYSCOMD
Nuclear Power Engineering (CEC)	572	15-20 mos.	Penn. State U.....	NAVFACENGCOMD
			U. of Mich.....	NAVFACENGCOMD
Oceanography	440	2 yrs.	U. of Miami (Florida)*.....	NPGS
			U. of Washington.....	NPGS
			Texas A.&M.*.....	NPGS
			U. of Cal. (San Diego)*.....	NPGS
			M.I.T.....	NPGS
Petroleum Administration and Management	880	1 yr.	S.M.U.*.....	JAG
Petroleum Engineering (CEC)	630	1 yr.	U. of Texas.....	NAVFACENGCOMD
		6-12 mos.	Industry	
Petroleum Management	811	16 mos.	U. of Kansas.....	NAVSUPSYSCOMD
Political Science	680	2 yrs.	Fletcher School of Law and Diplomacy, Tufts.....	OPNAV (OP-61)
			Univ. of Washington.....	OPNAV (OP-61)
Procurement Management	815	1 yr.	U. of Mich.....	NAVSUPSYSCOMD
Public Relations	920	1 yr.	U. of Wisc.....	CHINFO
Religion	970	9 mos.	Various.....	Chief of Chaplains
Retailing	830	1 yr.	Michigan State*.....	NAVSUPSYSCOMD
Subsistence Technology	860	1 yr.	Mich. State*.....	NAVSUPSYSCOMD
Systems Inventory Management	819	2 yrs.	Harvard.....	NAVSUPSYSCOMD
Transportation Management	813	1 yr.	Mich. State*.....	NAVSUPSYSCOMD

\* No NROTC unit at institution.

## CURRICULA AT OTHER UNIVERSITIES

The curricula listed in this section are conducted entirely at civilian educational institutions. Quotas for enrollment must be approved by the Chief of Naval Personnel. The table indicates the duration of each curriculum, the location, and the curricular supervisory control authority. Administration of officer students in connection with educational matters is exercised by the Superintendent, Naval Postgraduate School, through the Commanding Officer, NROTC Unit, or through the Senior Officer Student at those institutions where no NROTC Unit is established.

The information on courses is taken from college catalogues, but is subject to change from year to year. Changes depend on scheduling problems at the educational institutions and on the academic backgrounds of students. Further detailed information can be obtained from the catalogue of the institution concerned, or by writing to the institution.

### BUSINESS ADMINISTRATION CURRICULUM NUMBER 810

#### At Harvard University

**OBJECTIVE**—To give emphasis to the following areas of study: (1) recognition of problems, (2) realistic administrative follow-through on decisions, (3) an understanding and realistic handling of human relations, (4) administrative powers in general, (5) the relationship of business to the government and to the public welfare, (6) the integration of business functions, and (7) the point of view of the Chief Executive and the directors responsible for over-all operations so as to give the student an effective start in the development of his managerial skills and an appreciation of the responsibilities of a business administrator.

Course length: Two years

Degree attainable: Master of Business Administration

Typical Curriculum:

#### *First Year* (All courses required)

Elements of Administration:  
Finance  
Human Behavior in Organizations I and II  
Organizational Problems  
Managerial Economics, Reporting,  
and Control I and II  
Managerial Economics, Reporting,  
and Control III and IV  
Marketing  
Planning and the Business Environment  
Production  
Written Analysis of Cases

#### *Second Year* (10 half-year courses required)

Business Policy (Required)  
Courses in General Business Management  
Courses in Industrial and Financial Accounting  
Courses in Production/Manufacturing  
Courses in Finance/Investment  
Courses in Advanced/International Economics  
Courses in Personnel Administration/  
Human Relations  
Courses in Marketing/Sales/Merchandising  
Courses in Transportation  
Courses in Military Management  
Courses in Taxation  
Courses in Foreign Operations  
Courses in Probability and Statistics  
for Business Decisions  
Courses in Industrial Procurement

#### At Stanford University

**OBJECTIVE**—To give the student a foundation in the following areas: (1) the external environment of the commercial firm, (2) the internal and organizational environment of the firm, (3) quantitative methods and tools of control, and (4) the management of major functions; to give the student an opportunity to apply the knowledge, skills, and attitudes acquired to the solution of action-oriented problems involving the entire commercial enterprise.

Course length: Two years

Degree attainable: Master of Business Administration

Typical Curriculum:

#### *Required—First Year*

Organization Behavior  
Marketing Management I & II  
Quantitative Methods I, II & III  
Business Economics I & II  
Management Accounting I & II  
Business Finance I & II  
Manufacturing I & II  
Employment Relationships

#### *Second Year*

Courses in Industrial and Financial Accounting, Audit,  
Comptrollership  
Courses in Production/Manufacturing  
Courses in Finance/Investment/Banking  
Courses in Personnel Administration/Industrial  
Relations  
Courses in Marketing/Sales  
Courses in Transportation  
Courses in Insurance/Risk Management  
Courses in Advanced Economics/International Trade  
Courses in Research/Small Business Management  
Courses in Business Information Systems Data  
Processing  
Courses in Purchasing



**CIVIL ENGINEERING (ADVANCED)  
CURRICULUM NUMBER 470**

At: Georgia Institute of Technology  
Massachusetts Institute of Technology  
Princeton University  
Purdue University  
Rensselaer Polytechnic Institute  
Stanford University  
Texas A&M  
Tulane University  
University of California (Berkeley)  
University of Colorado  
University of Illinois  
University of Michigan  
University of Minnesota  
University of Washington

**OBJECTIVE**—To educate officers for civil engineering duties. Options are available in all major fields of civil engineering. Typical options are: construction engineering, structures, soil mechanics, sanitary engineering, waterfront facilities, facilities planning, and civil engineering administration. Officers without previous civil engineering education would undertake a two-year curriculum; officers holding a Bachelor of Civil Engineering degree would undertake a one-year curriculum. This program is to qualify line officers (1100) for civil engineering duties and to provide advanced education for Civil Engineering Corps officers (5100).

Course length: One to two years

Degree attainable: Master of Science in Civil Engineering

Typical Curriculum: (For two-year Structures Option)

*First Year*

Contracts and Specifications  
Mathematics  
Engineering & Construction Economy  
Structures Theory I, II  
Elementary Mechanics  
Geology for Engineers  
Digital Computers  
Properties of Soils  
Properties of Concrete  
Behavior and Design of Metal Structures  
Sanitary Engineering Processes

*Second Year*

Reinforced Concrete Design  
Advanced Mathematics  
Soil Mechanics  
Hydraulics-Surface drainage  
Advance Structure Analysis  
Behavior of Concrete Members  
Applied Soil Mechanics  
Special Problems  
Structural Design in Metals  
Applied Structural Mechanics  
Foundation Engineering

**ELECTRICAL ENGINEERING (CEC)  
CURRICULUM NUMBER 471**

At University of Michigan

**OBJECTIVE**—To provide advanced education for selected CEC officers in electrical engineering with emphasis on power plants and electrical utility distribution.

Course length: 15-24 months

Degree attainable: Master of Science in Electrical Engineering

**ENGINEERING ELECTRONICS (CEC)  
CURRICULUM NUMBER 472**

At University of Michigan

**OBJECTIVE**—To provide advanced education for selected CEC officers in the field of electronics with options in communication engineering, computer engineering, engineering systems and design, electromagnetic field theory, and microwave engineering.

Course length: 12 to 18 months

Degree attainable: Master of Science in Engineering Electronics

**FINANCIAL MANAGEMENT  
CURRICULUM NUMBER 812**

At George Washington University

**OBJECTIVE**—To develop in officers of mature judgment and a broad background of professional experience the ability to interpret and analyze operational statistics for the purpose of developing standards of performance; to provide a periodic review of operations in order to denote areas of management which are not meeting standards; to review budget estimates; and to plan programs for the improvement of management economy and efficiency through better organization, administration and procedures and better utilization of manpower, materials, facilities, funds and time. The course is designed to give graduates a working knowledge of managerial controls adequate for assignment to financial management duties as a normal preparation for command and executive billets in the shore establishment.

Course length: One year

Degree attainable: Master of Science in Business Administration

Typical Curriculum:

*Undergraduate:*

Survey of Accounting  
Industrial and Governmental Economics  
Statistical Decision Making  
Management Communication

*Graduate:*

Cost Accounting  
Managerial Accounting

Internal Control and Auditing  
 Survey of Data Processing  
 Financial Management  
 Seminar in Marketing  
 Business Organization and Management  
 Management Engineering  
 Readings and Conferences in Financial Management  
 Research Seminar  
 Research Seminar in Comptrollership  
 Human Relations in Administration  
 Governmental Budgeting

### **HYDROGRAPHIC ENGINEERING (GEODESY) CURRICULUM NUMBER 475**

At Ohio State University

**OBJECTIVE**—To prepare officers for assignment to duties at the Oceanographic Office, on geodetic survey expeditions, and on fleet staffs. The curriculum presents a fundamental theoretical knowledge of geodesy, cartography, and photogrammetry, particularly as applied to hydrographic surveying and the compilation and production of charts and maps.

Course length: Two years

Degree attainable: Master of Science in Geodesy

### **INTERNATIONAL LAW CURRICULUM NUMBER 672**

At George Washington University

**OBJECTIVE**—To prepare Law Specialists (1620) for duties involving problems of international law. The course encompasses international law and agreements including the law of air, sea, and space, legal aspects of U.S. foreign relations, negotiations, and legal regulation of international coercion. A thesis on a topic of significant international law interest is required. In addition, certain studies of a geographic area selected by the student will be conducted.

Course length: One year

Degree attainable: Master of Laws

### **INTERNATIONAL RELATIONS CURRICULUM NUMBER 671**

At: American University  
 Harvard University

**OBJECTIVE**—To provide a broad understanding of the forces and factors in international relations to equip officers to meet responsibilities involving knowledge of the international situation, including awareness of the role of sea power in world affairs.

Course length: One year

Degree attainable: Master of Arts

### **LAW CURRICULUM NUMBER 881**

(Army Judge Advocate Officers Advanced Course)

At University of Virginia

**OBJECTIVE**—To prepare more experienced Law Specialists (1620) for advanced staff responsibilities in the various legal fields. The course encompasses all branches of military law with emphasis on the administration of the Uniform Code of Military Justice, military affairs, civil affairs arising out of the operation of or litigation of military law, military reservations, international law including the laws of war, procurement and contract law, and legal assistance to military personnel.

Course length: Nine months

### **MANAGEMENT AND INDUSTRIAL ENGINEERING CURRICULUM NUMBER 540**

At Rensselaer Polytechnic Institute

**OBJECTIVE**—To prepare selected officers for managerial and industrial engineering billets in the Navy's industrial organization. The curriculum majors in industrial engineering and its application to managerial problems.

Course length: One year

Degree attainable: Master of Science in Management Engineering

Typical Curriculum:

#### *Summer:*

Review of Quantitative Methods  
 Statistical Methods  
 Law in Management and Engineering  
 Data Processing

#### *Fall:*

Cost Finding and Control  
 New Product Problems or  
 Organization and Management of Marketing  
 Organization Planning & Development  
 Industrial Relations  
 Production Management I

#### *Spring:*

Administrative Practice and Behavior  
 Financial Planning and Control  
 Seminar in Management  
 Production Management II  
 Analytical Methods in Management

### **MECHANICAL ENGINEERING (CEC) CURRICULUM NUMBER 473**

At Rensselaer Polytechnic Institute

**OBJECTIVE**—To provide advanced education for selected CEC officers in mechanical engineering with emphasis on power plants, heating and ventilation.

Course length: One year

Degree attainable: Master of Science in Mechanical Engineering

### **METALLURGICAL ENGINEERING CURRICULUM NUMBER 640**

At Carnegie Institute of Technology

**OBJECTIVE**—To obtain the maximum possible metallurgical background in a short program designed specifically for the graduate of the Naval Construction and Engineering Curriculum.

Course length: Nine months

Degree attainable: Bachelor of Science in Metallurgy

### **NAVAL CONSTRUCTION AND ENGINEERING CURRICULUM NUMBER 510**

At Massachusetts Institute of Technology

**OBJECTIVE**—To qualify selected officers for duty assignments in the fields of naval construction and marine engineering. The curricula are arranged to provide a broad capability in naval architecture and an exceptional capability in one option or specialty. Options are available in the following areas: hull design and construction, marine electrical engineering, electronics engineering and ship propulsion engineering. Selection of options is made after completion of the first summer term. Exceptional students are encouraged to pursue advanced work at the doctoral level. Successful completion of this curriculum leads to "Engineering Duty" designation (1400).

Course length: Three years

Degree attainable: Master of Science in Naval Architecture and Marine Engineering and the Degree of Naval Engineer

Typical Curriculum:  
(Hull Design and Construction Option)

#### *First Summer:*

Strength of Materials and Dynamics  
Applied Hydrostatics  
Review of Mathematics

#### *First Year:*

Structural Mechanics  
Fluid Mechanics  
Thermodynamics  
History of Naval Ships  
Advanced Calculus for Engineers  
Naval Structural Engineering  
Heat Transfer  
Introduction to Nuclear Physics  
Principles of Naval Architecture  
Naval Ship General Arrangements I  
Introduction to Probability and Random Variables

#### *Second Summer:*

Digital Computer Program Systems  
Advanced Calculus for Engineers

#### *Second Year:*

Advanced Hydromechanics I and II  
Properties of Metals  
Naval Structural Theory I and II  
Naval Ship Propulsion I  
Mechanical Vibration  
Naval Ship General Arrangements II  
Naval Structural Analysis  
Advanced Mechanics  
Properties of Metals  
Electives: Experimental Hydrodynamics  
Naval Structural Design I  
Naval Electrical Engineering

#### *Third Summer:*

Industrial Tour

#### *Third Year:*

Advanced Structural Mechanics  
Experimental Stress Analysis  
Principles of Ship Design  
Principles of Naval Ship Design  
Hydroacoustics  
Naval Ship Propulsion II  
Electives: Naval Structural Design II  
Buckling of Structures  
Plasticity  
Thesis

### **NUCLEAR ENGINEERING (ADVANCED) CURRICULUM NUMBER 520**

At Massachusetts Institute of Technology

**OBJECTIVE**—To qualify officers for the technical direction of nuclear power development in the Navy. Graduates of this program can normally expect to be assigned duties within the nuclear power development program under the direction of the NAVSHIPSYS COMD.

Course length: 14 months

Degree attainable: Master of Science

### **NUCLEAR POWER ENGINEERING (CEC) CURRICULUM NUMBER 572**

At: The Pennsylvania State University  
University of Michigan

**OBJECTIVE**—To provide education for selected CEC officers in nuclear power engineering. Graduates of this curriculum will normally be assigned duties in the shore nuclear power program under the technical direction of the NAVFACENG COMD.

Course length: 15 to 20 months

Degree attainable: Master of Science



### OCEANOGRAPHY CURRICULUM NUMBER 440

At: University of Washington  
Texas A&M College  
University of Miami (Florida)  
University of California (San Diego)  
Massachusetts Institute of Technology

**OBJECTIVE**—To prepare officers for assignment to billets requiring comprehensive theoretical and practical foundation in the various aspects of oceanography. Students may specialize in physical, biological, chemical, or geological oceanography. Entering students are expected to have a baccalaureate degree in physics, mathematics, meteorology, geophysics, or engineering, including the following undergraduate work: mathematics through differential equations (about 20 semester hours), physics (about 25 semester hours), chemistry through quantitative analysis, and introductory courses in biology, oceanography, geology, and meteorology.

Course length: Two years

Degree attainable: Master of Science in Oceanography

### PETROLEUM ADMINISTRATION AND MANAGEMENT (Gas, Oil and Water Rights)

#### CURRICULUM NUMBER 880

At Southern Methodist University

**OBJECTIVE**—To provide Law Specialists (1620) with a study of government regulations in oil and gas law taxation problems, and special research and study of the evolution of law concerning water rights, current law affecting these rights, and technical problems attendant thereto so as to prepare them for assignment to billets concerned with the administration and management of the Naval Petroleum and Oil Shale Reserves and with the special problems in the field of water rights.

Course length: One year

Degree attainable: Master of Laws in Oil and Gas

### PETROLEUM ENGINEERING (CEC) CURRICULUM NUMBER 630

At University of Texas  
and in the petroleum industry

**OBJECTIVE**—To prepare selected CEC officers for assignments to duty involving the administration and operations of Naval Petroleum and Oil Shale Reserves. The curriculum provides the student with a knowledge of petroleum development and production procedures, geology, petroleum economics and reservoir engineering.

Course length: One year of academic work followed by

up to one year in the field with a major oil company

Degree attainable: Master of Science in Petroleum Engineering

### POLITICAL SCIENCE CURRICULUM NUMBER 680

At: The Fletcher School of Law and Diplomacy at Tufts  
Graduate School of Public Affairs at University of Washington

**OBJECTIVE**—To equip a limited number of intellectually mature officers with a broad professional background in international relations in order that they may provide professional advice and assistance in the formulation and execution of national policy. Studies should be specifically directed toward obtaining sound knowledge and understanding in:

(1) The theory of international politics, economics, law, and U.S. diplomatic history.

(2) The politics, geography and history of one of the following regions of the world: Europe, Asia, Africa, Western Hemisphere.

(3) The history, role and importance of world-wide and regional international organizations.

(4) Development and execution of U.S. political, military and economic policy as it pertains to U.S. foreign relations.

Course length: Two years

Degree attainable: Master of Arts

### PROCUREMENT MANAGEMENT CURRICULUM NUMBER 815

At University of Michigan

**OBJECTIVE**—To provide officers of the Supply Corps with graduate level education in the field of military and commercial procurement:

Course length: One year

Degree attainable: Master of Business Administration

### PUBLIC RELATIONS CURRICULUM NUMBER 920

At University of Wisconsin

**OBJECTIVE**—To provide advanced qualifications of officers in the field of public relations. Officers selected for this program must have previous education or experience in public information and public relations. The curriculum will be made up from regular course offerings of the university and will be based on an officer student's background and particular interest within the curricular area.

Course length: One year

Degree attainable: Master of Arts in Public Relations

**RELIGION  
CURRICULUM NUMBER 970**

At: Harvard University  
Yale University  
Catholic University  
University of Chicago  
University of Notre Dame  
Fordham University  
Union Theological Seminary

**OBJECTIVE**—To broaden the education of officer students in such fields as psychology, theology, homiletics, and counseling, hospital ministry and education.

Course length: 9 months

**RETAILING  
CURRICULUM NUMBER 830**

At Michigan State University

**OBJECTIVE**—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of retailing. Emphasis is placed on consumer markets, sales promotion, merchandise and merchandising, and the management functions associated therewith.

Course length: One year

Degree attainable: Master of Business Administration

**SUBSISTENCE TECHNOLOGY  
CURRICULUM NUMBER 860**

At Michigan State University

**OBJECTIVE**—To provide officers of the Supply Corps with graduate level education in the field of food management.

Course length: One year

Degree attainable: Master of Business Administration

**SYSTEMS INVENTORY MANAGEMENT  
CURRICULUM NUMBER 819**

At Harvard University

**OBJECTIVE**—To provide officers of the Supply Corps with a well-grounded education at the graduate level in the scientific methods of inventory management.

Course length: Two years

Degree attainable: Master of Business Administration

Typical Curriculum:

*First Year: (Required)*

Elements of Administration:

Finance

Human Behavior in Organizations I and II

Organizational Problems

Managerial Economics, Report, and Control I and IV  
Managerial Economics, Reporting, and  
Control II and III

Marketing

Planning and the Business Environment

Production

Written Analysis of Cases

*Second Year: (Required)*

Management Information Systems

Business Logistics

Financial Accounting I and II

Seminar in Military Marketing and Project

Management

*Second Year: (Electives) (Four to be selected)*

Cost Administration

Industrial Procurement

Managing Technological Change

Planning and Controlling Production

\*Analysis of Quantitative Data I and II

\*Probability and Statistics for Business

Decisions I and II

\*Topics in Operations Analysis I and II

\*Management Economics

\*Prerequisite—Mathematics through Differential Calculus

**TRANSPORTATION MANAGEMENT  
CURRICULUM NUMBER 813**

At Michigan State University

**OBJECTIVE**—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of transportation management.

Course length: One year

Degree attainable: Master of Business Administration

Typical Curriculum:

Basic Accounting II

Financial Management

Basic Marketing

Basic Statistics I

Accounting for Financial and Profit  
Management II

Problems in Business Economics

Basic Statistics II

Transportation Policy

Accounting for Financial and Profit  
Management III

Human Problems in Administration

Social Problems in Administration

Marketing Management

Transportation Seminar



*King Hall with Spanagel Hall in background*



*Spanagel Hall with Breezeway to King Hall Auditorium*



*ACADEMIC DEPARTMENTS*  
*and*  
*COURSE DESCRIPTIONS*

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## DEPARTMENT OF AERONAUTICS

RICHARD WILLIAM BELL, Professor of Aeronautics; Chairman (1951),\* A.B., Oberlin College, 1939; Ae.E., California Institute of Technology, 1941; Ph.D., 1958.

ERIC JOHN ANDREWS, Professor of Aeronautics (1959); Honors B.S., Aero. Eng., Univ. of London, 1936.

DANIEL PETER BENCZE, Lieutenant (junior grade), U.S. Naval Reserve; Instructor in Aeronautics (1965); B.S., Univ. of Notre Dame, 1964; M.S., Massachusetts Institute of Technology, 1965.

WENDELL MAROIS COATES, Distinguished Professor and/Professor of Aeronautics (1931); A.B.; Williams College, 1919; M.S., Univ. of Michigan, 1923; D.Sc., 1929.

ALLEN EUGENE FUHS, Professor of Aeronautics (1966); B.S.M.E., Univ. of New Mexico, 1951; M.S.M.E., California Institute of Technology, 1955; Ph.D., 1958.

THEODORE HENRY GAWAIN, Professor of Aeronautics (1951); B.S., Univ. of Pennsylvania, 1940; D.Sc., Massachusetts Institute of Technology, 1944.

ULRICH HAUPT, Associate Professor of Aeronautics (1954); Dipl. Ing., Institute of Technology, Darmstadt, 1934.

GEORGE JUDSON HIGGINS, Professor of Aeronautics (1942); B.S., in Eng. (AeE), Univ. of Michigan, 1923; Ae.E., 1934.

CHARLES HORACE KAHR, JR., Professor of Aeronautics (1947); B.S., Univ. of Michigan, 1944; M.S., 1945.

HENRY LEBRECHT KOHLER, Professor of Aeronautics (1943); B.S. in M.E., Univ. of Illinois, 1929; M.S. in M.E., Yale Univ., 1930; M.E., 1931.

DONALD MERRILL LAYTON, Commander, U.S. Navy; Assistant Professor of Aeronautics (1965); B.S., Naval Academy, 1945; B.S. A.E., Naval Postgraduate School, 1953; M.S. in A.E., Princeton Univ., 1954.

GERALD HERBERT LINDSEY, Associate Professor of Aeronautics (1965); B.E.S. in M.E., Brigham Young Univ., 1960; M.S., 1962; Ph.D., California Institute of Technology, 1966.

JAMES AVERY MILLER, Associate Professor of Aeronautics (1963); B.S. in M.E., Stanford Univ., 1955; M.S. in M.E., 1957; Ph.D., Illinois Institute of Technology, 1963.

ROY EARL REICHENBACH, Associate Professor of Aeronautics (1962); B.M.E., Ohio State Univ., 1956; M.S., 1956; Ph.D., California Institute of Technology, 1960.

LOUIS VINCENT SCHMIDT, Associate Professor of Aeronautics (1964); B.S., California Institute of Technology, 1946; M.S., 1948; Ae.E., 1950; Ph.D., 1963.

CAMERON MACPHERSON SMITH, Professor of Aeronautics (1965); B.S. in C.E., Univ. of Washington, 1940; M.S. in C.E., 1940; M.E., Yale Univ., 1942; D. Eng., 1947.

MICHAEL HANS VAVRA, Professor of Aeronautics (1947); Dipl. Ing., Swiss Federal Institute of Technology, 1934; Ph.D., Univ. of Vienna, 1958.

DAVID CLARK WOOTEN, Lieutenant, U.S. Naval Reserve; Instructor in Aeronautics (1967); B.A., Rice Univ., 1960; M.S., 1962; Ph.D., (Applied Mechanics and Physics), 1966.

ROBERT DIEFENDORF ZUCKER, Associate Professor of Aeronautics (1965); B.S. in M.E., Massachusetts Institute of Technology, 1946; M.M.E., Univ. of Louisville, 1958; Ph.D., Univ. of Arizona, 1966.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES  
IN AERONAUTICAL ENGINEERING

The following are academic requirements for the award of these degrees as determined by the Aeronautical Department. In addition, the general minimum requirements as determined by the Academic Council must also be satisfied.

The entrance requirement to these programs is a baccalaureate degree in engineering or science, with minimum coverage in basic prerequisite sciences in semester hours as follows: mathematics (20), basic engineering (30), electrical engineering (14), physics (8), and chemistry (8). Students entering with approved standing, but following a significant lapse in continuity with previous academic work, normally will take refresher courses in engineering fundamentals and mathematics at the upper division level before entering into the degree programs.

Final approval of programs leading to degrees in Aeronautical Engineering is to be obtained from the Chairman, Department of Aeronautics.

BACHELOR OF SCIENCE IN AERONAUTICAL  
ENGINEERING

1. The entrance requirement to this program is a baccalaureate degree in engineering or science, with minimum coverage in basic prerequisite sciences in semester hours as follows:

Mathematics .....	20
Basic engineering .....	30
Electrical engineering .....	14
Physics .....	8
Chemistry .....	8

Students entering with approved standing, but following a significant lapse in continuity with previous academic work, normally will take refresher courses in engineering fundamentals and mathematics at the upper division level before entering into the degree programs.

2. Students who do not enter candidacy for an advanced degree may earn the Bachelor of Science in Aeronautical Engineering degree in an approved curriculum including a minimum of 60 credits in courses 3000-3999, to be drawn from the four required fields: mathematics, flight structures, flow dynamics, and flight systems technology. These courses normally begin following two quarters of refresher work in fundamentals. Coverage in mathematics will include one



course in addition to vector analysis, preferably in probability and statistics. The degree of emphasis among other fields may be varied, but must include modern developments in performance and control of aerospace vehicles, in gas dynamics, and in systems design. In addition to mathematics a minimum of 8 credits in courses 2000-3999 usually will be taken outside the major department.

### MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

1. Students who have a major in aeronautics, and who have earned the baccalaureate degree in the previous year, may apply for admission directly to graduate status. Other students normally will be selected to graduate standing at the end of three quarters in residence.

2. The Master of Science in Aeronautical Engineering degree requires a minimum of 36 graduate course credits to be completed following selection to graduate standing, at least 20 of them in courses 4000-4999, plus an acceptable thesis (this requirement may be waived by the Chairman, Department of Aeronautics; accordingly, the minimum number of required graduate course credits will be increased to 44). At least one advanced mathematics course in addition to vector calculus is required. Core courses normally will be included in engineering dynamics, continuum mechanics and boundary layer flows.

3. The courses of study may be arranged in consultation with the thesis advisor to meet the needs of the research program. Excessive specialization is not encouraged, but it is expected that beyond the core subjects the candidate will concentrate on two related sequences in Aeronautics plus requisite extra-departmental courses.

### AERONAUTICAL ENGINEER

1. Students entering with a time lapse since earning a baccalaureate degree in engineering or science can earn the Aeronautical Engineering degree in three years. Admission to candidacy for this degree occurs during the second year of residence, following completion of the Aeronautics graduate examination.

2. This degree requires a minimum of 80 graduate course credits to be completed following selection to graduate standing, normally to include graduate core coverage as listed under the Master's degree, plus an acceptable thesis. Not less than 40 of these graduate credits must be in courses 4000-4999; aeronautics credits to be counted in this total must also be in courses 4000-4999. The program of study will be developed for each student in consultation with his thesis advisor. A variety of subjects to provide a broad foundation in aero-space science, and in engineering applications suitable to the major specialty, generally will be required.

### AERONAUTICS

AE 0001 AERONAUTICAL LECTURE SERIES (0-1). Lectures on general aeronautical engineering subjects by prominent authorities from the Navy Department, research laboratories and the industry.

AE 0010 AERONAUTICAL SEMINAR (0-2). Discussion of aeronautical development and reports in research by faculty, officer-students, and guest lecturers.

### Upper Division Courses

AE 2201 AERO-STRUCTURES I (3-2). Elements of aero-structural analysis; the relationship between loads, structural geometry, and defined properties of materials. Stress, strain, and equilibrium; application to typical aero-structures. TEXTS: Peery, *Aircraft Structures*; Shanley, *Strength of Materials*. PREREQUISITE: Engineering Mechanics.

AE 2202 AERO-STRUCTURES II (3-2). The second course in elements of aero-structural analysis, with emphasis on the relationship between loads and deflections. The energy method of solution for determinate and indeterminate structures. TEXTS: Peery, *Aircraft Structures*; Shanley, *Strength of Materials*. PREREQUISITE: AE 2201.

AE 2301 TECHNICAL AERODYNAMICS I (3-0). Introduction to fluid mechanics: properties of fluids, conservation laws, and Bernoulli's equation. Dimensional analysis and dynamic similarity. Experimental techniques: wind tunnels, models and measurements; applications to full scale. Airfoils and auxiliary lift devices; concept of viscous flow, boundary layer and flow separation; influence of compressibility. TEXT: Dwinell, *Principles of Aerodynamics*. PREREQUISITE: Engineering Mechanics.

AE 2302 TECHNICAL AERODYNAMICS II (3-2). Continuation of AE 2301. Fluid forces acting on bodies and wings; downwash and induced drag. Applications to performance, stability and control. Comparison of aircraft types: propeller, jet, rocket, V/STOL, and helicopter. TEXT: Dwinell, *Principles of Aerodynamics*. PREREQUISITE: AE 2301.

AE 2401 ENGINEERING THERMODYNAMICS (3-2). (See listing of ME 2101.)

AE 2402 ELEMENTARY GAS DYNAMICS (3-2). The thermodynamics and dynamics of fluid flow. One dimensional isentropic flows. Normal and oblique shocks. Prandtl-Meyer flow. Fanno and Rayleigh flow. TEXTS: Rotty, *Introduction to Gas Dynamics*; Shapiro, *The Dynamics and Thermodynamics of Compressible Fluid Flow, Vol. 1*. PREREQUISITES: AE 2401; AE 2301.

AE 2801 AERO-LABORATORIES, INTRODUCTION TO (0-3). An introduction to experimental techniques, measurements, instrumentation, and data reduction. Familiarization with laboratories and equipment. TEXTS: Messersmith, Warner, Olsen, *Mechanical Engineering Laboratory*; Schenk, *Theories of Engineering Experimentation*. PREREQUISITE: AE 2201 concurrently.

AE 2802 AERO-STRUCTURES LABORATORY (0-3). Fundamentals of instrumentation and testing techniques for aero-structures, including strain gages and photo-elasticity. Analysis and test of a full scale wing. TEXT: Dally and Riley, *Experimental Stress Analysis*. PREREQUISITES: AE 2801 or equivalent; AE 2201.

### Upper Division or Graduate Courses

AE 3115 ENGINEERING DYNAMICS I (3-2). Particle kinematics and kinetics, orbital motion, Lagrange's equations for a particle and a system of particles, Lagrange multi-

pliers used to determine constraints, rigid body dynamics and inertia tensor. TEXTS: Greenwood, *Principles of Dynamics*; Pipes, *Applied Mathematics for Engineering and Physics*. PREREQUISITES: AE 2202; AE 2302.

AE 3211 AERO-STRUCTURAL PERFORMANCE I (3-2). Curved beams, torsion of non-circular sections. Elastic stability, columns, beam columns, and buckling of thin-sheet structures. Theories of failure. TEXTS: Peery, *Aircraft Structures*; Sechler, *Elasticity in Engineering*. PREREQUISITE: AE 2202.

AE 3212 AERO-STRUCTURAL PERFORMANCE II (3-2). Matrix methods of analysis of wing and fuselage structures. Introduction to the theory of elasticity and thermal stresses. TEXTS: Bruhn and Schmidt, *Analysis and Design of Aircraft Structures*; Martin, *Introduction to Matrix Methods of Structural Analysis*; Boley and Weiner, *Theory of Thermal Stresses*. PREREQUISITE: AE 3211.

AE 3232 ELEMENTS OF AEROELASTICITY (3-2). Fundamentals of static and dynamic aeroelasticity including: divergence, control reversal, lift distributions of elastic wing, flutter, and impulsive loadings. TEXTS: Abramson, *The Dynamics of Airplanes*; Fung, *The Theory of Aeroelasticity*; Bisplinghoff, Ashley, Halfman, *Aeroelasticity*. PREREQUISITE: AE 3115.

AE 3271 FUNDAMENTALS OF FLIGHT VEHICLE DESIGN (3-3). Development of a basic understanding for design problems through the integration of various disciplines into an overall system; evaluating requirements for airworthiness and minimum weight; determining structural strength of component parts. General trends for future developments. TEXTS: Bruhn, *Analysis and Design of Flight Vehicle Structure*; Bonney, *Principle of Guided Missile Design*; Peery, *Aircraft Structures*. PREREQUISITES: AE 3115; AE 3212.

AE 3303 AIRCRAFT PERFORMANCE (3-2). Aerodynamics of an aircraft; determination of lift, drag, and drag polar of aircraft. Effect of compressibility, steady state power performance, power requirements, minimum and maximum speed, rate of climb, range and endurance. Energy methods. Take-off, landing, performance. TEXTS: Perkins and Hage, *Aircraft Performance, Stability and Control*; Dommasch, Sherby, Connolly, *Airplane Aerodynamics*; NAVWEPS 00-80T, *Aerodynamics for Naval Aviators*. PREREQUISITE: AE 2302.

AE 3321 FLIGHT DYNAMICS I (3-2). Longitudinal static stability; control surface design and performance. Stick-fixed and stick-free stability and margins, neutral and maneuver points, center of gravity limits. Stick-force and displacements. Dihedral effects, lateral static stability; rudder lock, adverse yaw. Aeroelastic effects on static stability. TEXTS: Perkins and Hage, *Aircraft Performance, Stability and Control*; Dommasch, Sherby, Connolly, *Airplane Aerodynamics*; NACA Report No. 927; MIL SPEC 8785 (ASG). PREREQUISITE: AE 3303.

AE 3322 FLIGHT DYNAMICS II (3-2). The dynamic stability problem; Euler's equation of motion; longitudinal dynamics; stability derivatives. Nature of general and tran-

sient motions, effects of cross-coupling, effect of changes of variables, aeroelastic effects on dynamic stability. TEXTS: Perkins and Hage, *Aircraft Performance, Stability and Control*; Babister, *Aircraft Stability and Control*; Seckel, *Stability and Control of Airplanes*. PREREQUISITE: AE 3321.

AE 3331 FLIGHT EVALUATION TECHNIQUES I (2-0). Quantitative and qualitative techniques for evaluation of aircraft performance in flight. Instrumentation. Course work supported by AE 3821, a flying laboratory in suitable Naval aircraft. TEXTS: NATC Patuxent, Performance Test Manual; NATC Patuxent, Engine Performance Manual. PREREQUISITE: AE 3303.

AE 3332 FLIGHT EVALUATION TECHNIQUES II (2-0). Techniques for evaluation of aircraft static and dynamic stability and control characteristics. Course work supported by AE 3832, a flying laboratory in suitable Naval aircraft. TEXTS: NATC Patuxent, Stability and Control Manual; MIL SPEC 8785 (ASG). PREREQUISITE: AE 3331.

AE 3340 FUNDAMENTALS OF AUTOMATIC CONTROL (3-2). The requirements for automatic controls. The basic techniques for achieving and evaluating satisfactory controls. Aeroelastic effects. TEXTS: Etkin, *Dynamics of Flight, Stability and Control*; Raven, *Automatic Control Engineering*. PREREQUISITE: AE 3322.

AE 3341 CONTROL SYSTEMS (3-3). (See listing of EE 3411.)

AE 3403 HEAT TRANSFER (3-2). Elements of heat transfer including steady and nonsteady conduction, free and forced convection, heat transfer with change in phase, thermal radiation, dimensional analysis, numerical and analog methods. TEXT: Holman, *Heat Transfer*. PREREQUISITES: AE 2401; AE 2301.

AE 3404 AIRCRAFT PROPULSION (3-2). Basic mechanics of thrust by jets, propellers or rotors. Momentum and blade element theory. Analysis of reciprocating engines, turbo-jet, turbo-prop, turbo-fan and ramjets. TEXTS: Nelson, *Airplane Propeller Principles*; Hesse & Mumford, *Jet Propulsion*, 2nd ed. PREREQUISITES: AE 2402; AE 3301.

AE 3501 FLUID DYNAMICS I (4-0). Fundamental concepts and governing equations of fluid dynamics in various coordinate systems. Continuity, momentum and energy equations. Laminar and turbulent flow fundamentals. Mostly restricted to incompressible fluids. TEXT: Shames, *Mechanics of Fluids*. PREREQUISITES: AE 2301; Vector Calculus and Differential Equations.

AE 3502 FLUID DYNAMICS II (4-0). Boundary layer concepts and equations, similarity concepts. Separation, analysis of wakes, universal velocity distributions. Method of small perturbation in compressible flow, theory of weak wave interactions. Unsteady motion. TEXTS: Shames, *Mechanics of Fluids*; Liepmann and Roshko, *Elements of Gas-Dynamics*. PREREQUISITE: AE 3501.

AE 3540 INTRODUCTION TO RE-ENTRY (3-2). The re-entry problem discussed from various viewpoints. Manned



and unmanned vehicles; limitations imposed on re-entry. TEXT: Notes. PREREQUISITES: AE 2202; AE 2302; AE 2402.

AE 3803 SUBSONIC LABORATORY (0-3). Introduction to aerodynamic investigations in a wind tunnel. TEXT: Pope, *Wind Tunnel Testing*. PREREQUISITE: AE 2302.

AE 3804 GAS DYNAMICS & PROPULSION LABORATORY (0-3). Laboratory techniques in one- and two-dimensional steady flow, one-dimensional unsteady flow, combustion. Tests of selected complete propulsion systems. TEXT: Keenan & Kaye, *Gas Tables*. PREREQUISITE: AE 2402.

AE 3805 ENGINEERING DYNAMICS LABORATORY (0-3). Experiments in the fundamentals of dynamics using the analog computer, shaker table, accelerometers, reluctance gages and strain gages. TEXT: Prepared Notes. PREREQUISITES: AE 3115 may be concurrent.

AE 3831 FLIGHT EVALUATION TECHNIQUE LAB I (0-4). A flight laboratory in the technical aerodynamics of airplanes pertinent to performance evaluation. TEXT: None. PREREQUISITE: AE 3331 concurrently.

AE 3832 FLIGHT EVALUATION TECHNIQUE LAB II (0-4). A flight laboratory in the technical aerodynamics of airplanes pertinent to static and dynamic stability and control. TEXT: None. PREREQUISITE: AE 3332 concurrently.

#### Graduate Courses

AE 4116 ENGINEERING DYNAMICS II (3-2). Variational methods and Hamilton's principle. Single degree of freedom systems: impulse, step and harmonic forcing functions; Duhamel superposition integral. Eigenvalue problems for lumped and continuous systems, including application to aircraft dynamics. TEXTS: Greenwood, *Principles of Dynamics*; Pipes, *Applied Mathematics for Engineering and Physics*. PREREQUISITE: AE 3115.

AE 4131 CONTINUUM MECHANICS (4-0). A development of the field equations for a continuum from a tensor approach. Parallel developments for fluid and solid continua emphasizing the differences and the similarities. TEXT: Frederick and Chang, *Continuum Mechanics*. PREREQUISITE: AE 2202.

AE 4132 SOLID MECHANICS I (4-0). A problem course in elasticity. St. Venant's theory of bending and torsion, two-dimensional problems of plane stress and plane strain, stress functions and strain potentials. TEXTS: Sokolnikoff, *Mathematical Theory of Elasticity*; Fung, *Foundations of Solid Mechanics*. PREREQUISITE: AE 4131.

AE 4133 SOLID MECHANICS II (4-0). A second problem course in elasticity. May be taken independently of AE 4132. Introduction to plate theory, energy theorems, approximate methods of solution, numerical methods. TEXTS: Sokolnikoff, *Mathematical Theory of Elasticity*; Fung, *Foundations of Solid Mechanics*. PREREQUISITE: AE 4131.

AE 4161 THEORY OF VISCO-ELASTICITY (4-0). A coverage of the basic elements of linear visco-elasticity with

applications to the analysis of solid propellants. TEXT: Instructor's Notes. PREREQUISITE: AE 4131.

AE 4162 THEORY OF PLASTICITY (4-0). A development of the plastic behavior of metals, emphasizing yield criteria, flow laws, and solutions of engineering problems. TEXT: Under study. PREREQUISITE: AE 4131.

AE 4241 FLIGHT VEHICLE STRUCTURAL ANALYSIS (3-2). Matrix analysis of airplane and missile structures: force and displacement methods, structural idealizations, and structural partitioning. TEXTS: Martin, *Introduction to Matrix Methods of Structural Analysis*; Bruhn, *Analysis and Design of Flight Vehicle Structure*. PREREQUISITES: AE 2202; AE 2302.

AE 4242 THEORY OF PLATE AND SHELL STRUCTURES (3-2). The theory of plates and shells applied to aircraft and missile structures. Classical topics: equilibrium, energy, boundary conditions, lateral loadings, buckling. Idealizations for matrix formulations. TEXT: Timoshenko, *Theory of Plates and Shells*; NASA publications; Technical Journal Reprints. PREREQUISITES: AE 4131; AE 4241.

AE 4251 STRUCTURAL DYNAMICS (4-0). Structural response to free, forced, and self-excited oscillations. Ground shock, ground wind, and silo-launch problems. Testing techniques, design criteria, and methods of analysis. Wave propagation in solids; dispersion of waves in bounded solids. TEXT: Hurty and Rubinstein, *Dynamics of Structure*. PREREQUISITES: AE 4116; AE 4131.

AE 4252 ADVANCED AEROELASTICITY (4-0). Static aeroelastic problems; wing divergence, control reversal, airframe stability. Self-excited vibration in structures. Aero-dynamic forcing functions, mechanism of flutter, and non-stationary airfoil theory. Transient loads, gusts, buffet and stall flutter. TEXTS: Fung, *Theory of Aeroelasticity*; Bisinghoff, Ashley, Halfman, *Aeroelasticity*. PREREQUISITE: AE 4251.

AE 4275 ADVANCED FLIGHT VEHICLE DESIGN (3-3). Preliminary design of specific aero-structural components to be integrated in a system, stressing required compromises for effective functional performance. Structural trends in aero-space vehicles and launchers. TEXTS: Pauser, Faget, Smith, *Manned Spacecraft*; Bruhn, *Analysis and Design of Flight Vehicle Structures*; Hall, *Systems Engineering*. PREREQUISITES: AE 4242; AE 3115 or equivalent.

AE 4304 FLIGHT VEHICLE RESPONSE (3-2). Dynamic stability and control of flight vehicles: longitudinal, lateral, and directional. Characteristics: controls fixed and free; programmed central inputs. Cross coupling effects. TEXTS: Perkins and Hage, *Aircraft Performance, Stability and Control*; Etkin, *Dynamics of Flight Stability and Control*; Seckel, *Stability and Control of Airplanes*. PREREQUISITE: AE 4116.

AE 4336 LOW SPEED FLIGHT MECHANICS (3-2). Stability and performance characteristics of low-speed aircraft. Ground effect phenomena. VTOL, STOL, and rotary wing aircraft; air cushion vehicles and compound flight



vehicles. TEXT: Seckel, *Stability and Control of Airplanes and Helicopters*. PREREQUISITE: AE 3303.

AE 4342 AUTOMATIC CONTROL I (3-2). Power controls and stability augmentation. Aircraft component and pilot transfer functions, and block diagram concept. Application of frequency response techniques, root locus methods and transient effects. System analysis of aircraft controls; cross-axis coupling. Performance specifications and response shaping. Aeroelastic effects on stability. TEXTS: Etkin, *Dynamics of Flight*; Raven, *Automatic Control Engineering*. PREREQUISITES: AE 3341; AE 4304 or AE 3321.

AE 4343 AUTOMATIC CONTROL II (3-2). Vehicle dynamics and interaction with augmentation devices and automatic controls. Automatic power control for deck recovery, time-modulated aerodynamic controls, missile control, and terrain following. Random processes and auto-correlation functions, Fourier transforms and power spectral densities. Optimal design. TEXTS: Etkin, *Dynamics of Flight*; Raven, *Automatic Control Engineering*. PREREQUISITE: AE 4342.

AE 4421 HEAT TRANSFER I (4-0). Introduction to the rate equations of heat and mass transfer; conductive heat transfer in steady and nonsteady state, and in one, two and three dimensions; analytic, analog and numerical methods of solution. TEXTS: Jacob, *Heat Transfer, Vols. I and II*; Schneider, *Conduction Heat Transfer*. PREREQUISITE: AE 4521.

AE 4422 HEAT TRANSFER II (4-0). Convective heat transfer in ducts and from exposed surfaces, laminar and turbulent flows. Analytic techniques, integral methods, experimental correlations. Effects of variations in thermophysical properties. TEXTS: Kays, *Convective Heat Transfer*; Spaulding, *Convective Mass Transfer*. PREREQUISITES: AE 4421; AE 4522.

AE 4423 HEAT TRANSFER III (4-0). Radiant heat transfer. Emissivities of solids and gases, black body radiation, grey body radiation. Geometric problems, net radiation interchange, the method of Oppenheim. TEXT: Jacob, *Heat Transfer, Vols. I and II*. PREREQUISITE: AE 4422.

AE 4424 HEAT TRANSFER IV (HYPERSONIC) (4-0). Heat transfer by convection and radiation in hypersonic flow, chemical changes, property variations occasioned by large temperature differences; re-entry heat transfer, re-entry mass transfer. TEXT: Dorrance, *Viscous Hypersonic Flow*. PREREQUISITES: AE 4423; AE 4462.

AE 4431 AEROTHERMODYNAMICS OF TURBOMACHINES (4-0). Application of fundamental laws of fluid dynamics and thermodynamics to the analysis of flows in turbomachines. TEXT: Vavra, *Aerothermodynamics and Flow in Turbomachines*. PREREQUISITE: AE 2402.

AE 4432 ADVANCED THEORY OF TURBOMACHINES (4-0). Advanced theory and methods for design and performance prediction of turbomachines. TEXT: Vavra, *Aerothermodynamics and Flow in Turbomachines*. PREREQUISITES: AE 4431; AE 4521.

AE 4433 ADVANCED TURBOPROPULSION SYSTEMS (4-0). Application of fluid dynamics, thermodynamics and stress analysis to the design of aero and space power plants. TEXT: Vavra, *Aerothermodynamics and Flow in Turbomachines*. PREREQUISITE: AE 4432.

AE 4434 TURBOPROPULSION SEMINAR (3-0). Individual assignments of advanced topics in the field of propulsion. TEXT: Under study. PREREQUISITE: AE 4433.

AE 4461 STATISTICAL THERMODYNAMICS (3-2). Fundamentals of statistical thermodynamics including kinetic theory of an ideal gas, distribution of molecular velocities, transport phenomena, Maxwell-Boltzman statistics, partition functions, and thermodynamic properties. TEXTS: Lee, Sears, Turcotte, *Statistical Thermodynamics*; Lee and Sears, *Thermodynamics*. PREREQUISITE: AE 2402.

AE 4462 COMBUSTION THERMODYNAMICS I (3-2). Thermodynamics of combustion, quantitative evaluation of rocket propellants, phenomenological chemical kinetics. Ionization and dissociation in gases, and relaxation phenomena. TEXTS: Penner, *Chemistry Problems in Jet Propulsion*; Williams, *Combustion Theory*. PREREQUISITE: AE 4461.

AE 4463 COMBUSTION THERMODYNAMICS II (3-2). Combustion thermodynamics emphasizing classical chemical kinetics and conservation of mass, momentum, and energy in reacting mixtures. TEXTS: Penner, *Chemistry Problems in Jet Propulsion*; Williams, *Combustion Theory*. PREREQUISITE: AE 4462.

AE 4464 AEROTHERMOCHEMISTRY (3-2). Chemical reactions in flow systems, with emphasis on the interplay between aerodynamics, physics, and chemistry. TEXTS: Penner, *Chemistry Problems in Jet Propulsion*; Williams, *Combustion Theory*. PREREQUISITE: AE 4463.

AE 4521 VECTOR MECHANICS OF FLUID FLOW (4-0). Vector concepts of fluid flow. Potential function, stream function, Biot-Savart law. Applications to airfoils and wings. TEXT: Under study. PREREQUISITES: MA 3260; AE 4131.

AE 4522 BOUNDARY LAYER FLOWS (4-0). Some exact solutions of the Navier-Stokes equations. Boundary layer concept and equations, momentum and energy integrals, stability and transition. The fundamentals of turbulent flow; laminar and turbulent boundary layers with arbitrary pressure gradient. TEXTS: Schlichting, *Boundary Layer Theory*; Instructor's Notes. PREREQUISITE: AE 4521.

AE 4523 FUNDAMENTALS OF COMPRESSIBLE FLOW (4-0). Two dimensional subsonic, transonic, and supersonic flows. Linearized small perturbation theory. Hodograph and series methods, methods of characteristics, wave reflection and interaction. Subsonic and transonic similarity rules. One dimensional nonsteady flow. Moving shocks. TEXT: Shapiro, *The Dynamics and Thermodynamics of Compressible Fluid Flow, Vols. I and II*. PREREQUISITES: AE 2402; AE 4131.

AE 4524 SUPERSONIC AERODYNAMICS (4-0). Three dimensional supersonic flow. Conical flow, slender body theory, similarity rules, wings of finite span. Supersonic lift-

ing line and lifting surface theories. Drag minimization, flow reversal theorems, interference effects and oscillating airfoils in subsonic and supersonic flow. TEXTS: Shapiro, *The Dynamics and Thermodynamics of Compressible Fluid Flow, Vols. I and II*; Ferri, *Elements of Aerodynamics of Supersonic Flow*. PREREQUISITE: AE 4523.

AE 4541 MISSILE TECHNOLOGY I (4-0). The first course in missile science and technology, emphasizing hypersonic flow. TEXTS: Martin, *Atmospheric re-entry*; Cox and Crabtree, *Elements of Hypersonic Aerodynamics*; Instructor's Notes. PREREQUISITE: AE 4523.

AE 4542 MISSILE TECHNOLOGY II (4-0). The second course in missile science and technology, emphasizing trajectories, dynamics of vehicles, and the plasma sheath. TEXTS: Martin, *Atmospheric Re-entry*; Instructor's Notes. PREREQUISITE: AE 4541.

AE 4543 MISSILE TECHNOLOGY III (4-0). The final course in a three course sequence in missile science and technology, stressing thermal protection of re-entry vehicles, test facilities and re-entry vehicle design. TEXTS: Martin, *Atmospheric Re-entry*; Instructor's Notes. PREREQUISITE: AE 4542.

AE 4550 ENGINEERING MAGNETOHYDRODYNAMICS (4-0). Current and future applications of magnetohydrodynamics including propulsion, power generation, the plasma sheath, and hypersonic test facilities. TEXTS: Sutton and Sherman, *Magnetohydrodynamics*; Arzimovich, *Element Plasma Physics*; Schercliff, *Magnetohydrodynamics*. PREREQUISITES: AE 4522; AE 4523; Electromagnetic Theory.

AE 4851 TURBOMACHINERY LABORATORY I (0-3). Measurements of overall performance of turbines and compressors. Data reduction, error analysis, and measurement techniques. TEXT: Under study. PREREQUISITE: AE 4431 concurrently.

AE 4852 TURBOMACHINERY LABORATORY II (0-3). Detailed investigations of the stationary and rotating components of turbomachines. Cascade test rigs, inter-stage data of turbomachines, and evaluation of loss coefficients. TEXT: Under study. PREREQUISITE: AE 4432 concurrently.

AE 4854 TURBOMACHINERY LABORATORY III (0-3). Individual assignments to current research projects in the field of turbomachines. TEXT: Under study. PREREQUISITE: AE 4434 concurrently.

**AVIATION SAFETY OFFICER PROGRAM**

THOMAS LEIGH LINDSAY, Lieutenant Commander, U.S. Navy; Assistant Professor of Aeronautical Engr. and Safety; B.S., Univ. of Notre Dame, 1954; M.S., Massachusetts Institute of Technology, 1961.

RICHARD GARDNER MILLS, Associate Professor of Aviation Medicine; M.D., Univ. of Michigan, 1955.

JAMES CHRISTIAN NIELSEN, Associate Professor of Aeronautical Engr. and Safety; B.S., Univ. of Washington, 1950; M.S., 1957.

LESTER CHARLES WIBLE, Assistant Professor of Aviation Accident Prevention and Crash Investigation; B.S., Naval Academy, 1945.

The Aviation Safety Officer Program is offered on a temporary additional duty basis to those Officers so ordered by the Chief of Naval Personnel. The following courses constitute the program and are taken simultaneously: AO 2310, AO 2320, AO 2360, and PY 2352.

Officers regularly enrolled in other curricula at the Postgraduate School may qualify as Aviation Safety Officers by completion of the following courses: AO 2301, AO 2302, and PY 2050.

**AVIATION***Upper Division Courses*

AO 2301 AERONAUTICAL ENGINEERING FOR AVIATORS (4-2). A survey of aeronautical engineering for the aviator and the Aviation Safety Officer. Material covered includes basic aerodynamics, subsonic and supersonic aircraft characteristics, aircraft performance, stability and control, and aircraft structural limitations. PREREQUISITES: Mathematics through college algebra and geometry; physics through mechanics and heat.

AO 2302 AVIATION ACCIDENT PREVENTION AND CRASH INVESTIGATION (3-2). This course consists of (a) a study of all existing Navy Department instructions covering all aspects of accident investigation and reporting

procedures, (b) methods and techniques of accident investigation, (c) implementation and use of a prevention program, and (d) aero medicine lectures on physiological factors in flight. PREREQUISITE: NW 2301 or may be taken concurrently with NW 2301.

AO 2310 AERO ENGINEERING SAFETY (6-0). A survey of aeronautical engineering for the aviator and the Aviation Safety Officer. Material covered includes basic aerodynamics, subsonic and supersonic aircraft characteristics, aircraft performance, stability and control, and aircraft structural limitations. (Includes mathematics review.)

AO 2320 AVIATION ACCIDENT PREVENTION AND CRASH INVESTIGATION (4-0). This course consists of (a) a study of all existing Navy Department instructions covering all aspects of accident investigation and reporting procedures, (b) methods and techniques of accident investigation, and (c) implementation and use of a prevention program.

AO 2360 AVIATION PHYSIOLOGY (2-0). A review of basic fundamentals of physiology with emphasis on the circulatory and respiratory systems with the objective of understanding the principles associated with the physiological stresses encountered in aviation. The role of the squadron flight surgeon in the squadron training program and his duties in aviation accident prevention, investigation and reporting.

**PSYCHOLOGY***Upper Division Courses*

PY 2050 GENERAL PSYCHOLOGY (3-0). A study of principles of rational and emotional processes in human thought and action.

PY 2352 PSYCHOLOGY IN ACCIDENT PREVENTION AND INVESTIGATION (4-0). A study of logical and psychological principles and practices useful in developing mental efficiency and emotional strength, designed especially for the Aviation Safety Officer Program.



## DEPARTMENT OF BUSINESS ADMINISTRATION AND ECONOMICS

JAMES MORGAN FREMGEN, Associate Professor of Accounting and Chairman (1965); B.S.C., Univ. of Notre Dame, 1954; M.B.A., Indiana Univ., 1955; D.B.A., 1961; C.P.A., State of Indiana, 1964.

WILLIAM RICHARDS BAKER, Commander, SC, U.S. Navy; Instructor in Management (1965); B.S., Naval Academy, 1945; Management, Naval Postgraduate School, 1958.

BARRY CASTRO, Associate Professor of Economics (1966); B.A., Hunter College, 1955; M.B.A., New York Univ., 1956; Ph.D., 1967.

WILLIAM HOWARD CHURCH, Professor of Management (1956); B.A., Whittier College, 1933; M.S.P.A., Univ. of Southern California, 1941.

JAMES BARRIE COWIE, Associate Professor of Management Science (1963); B.Sc. (honors), Glasgow Univ., 1958; C.I.A., 1959.

JERRY LEE DAKE, Assistant Professor of Management Science (1965); B.S., Purdue Univ., 1961; M.S., 1962.

LESLIE DARBYSHIRE, Professor of Management (1962); B.A., Univ. of Bristol, 1950; D.B.A., Univ. of Washington, 1957.

ROGER NILS FOLSOM, Lieutenant (junior grade), U.S. Naval Reserve; Assistant Professor of Economics (1965); A.B., Stanford Univ., 1959; M.A., Claremont Graduate School, 1964.

FENN CLARK HORTON, Associate Professor of Economics (1964); B.A., State Univ. of Iowa, 1950; M.A., Claremont Graduate School, 1967.

H. ARTHUR HOVERLAND, Associate Professor of Management (1963); B.S., Miami Univ., 1951; M.S., Univ. of Illinois, 1954; Ph.D., Univ. of Michigan, 1963.

JAMES KENNETH JOBE, Commander, U.S. Navy, Instructor in Leadership; A.B., George Washington Univ., 1963; M.A., 1964.

SIGMUND KRAUTHAMER, Associate Professor of Economics (1965); B.S., Ohio State Univ., 1949; Ph.D., Univ. of Minnesota, 1963.

PAUL EDWARD ROBERTS, JR., Assistant Professor of Economics (1966); A.B., Southern Illinois Univ., 1961; M.A., 1962.

JOHN DAVID SENDER, Associate Professor of Management (1957); B.S., Univ. of Illinois, 1945; M.S., 1948; Ph.D., 1965.

MELVIN JOHN STECKLER, Associate Professor of Management (1966); B.S.M.E., Univ. of Washington, 1949; M.B.A., 1957; D.B.A., Harvard Univ., 1967.

## DEPARTMENTAL REQUIREMENTS FOR THE DEGREE BACHELOR OF SCIENCE WITH MAJOR IN BUSINESS ADMINISTRATION

1. A candidate for the Bachelor of Science degree with a major in business administration must meet the general requirements for the baccalaureate degree. Additionally, he must meet the following specific requirements for the major:

a. A minimum of 34 quarter hours of course work at or above the 2000 level.

b. Successful completion or validation by advanced credit of approved courses in each of the following areas of study:

Behavioral Sciences  
Computers and Programming  
Economics  
Financial Management and Accounting  
Material Management  
Statistics

## DEPARTMENTAL REQUIREMENTS FOR THE DEGREE MASTER OF SCIENCE IN MANAGEMENT

1. A candidate for the degree of Master of Science in Management must complete satisfactorily either (a) a minimum of 58 quarter hours of graduate level course work or (b) a minimum of 50 quarter hours of graduate level course work and a thesis.

2. Core course requirements at the graduate level must be successfully completed or validated by advanced credit in each of the following areas:

Behavioral Sciences  
Data Processing  
Economics  
Financial Management and Accounting  
Management Policy  
Material Management  
Operations Research  
Statistics  
Systems Analysis

3. In addition to the core requirements, each candidate must complete an approved elective sequence, comprising either (a) a minimum of 12 quarter hours of graduate level course work or (b) a minimum of 4 quarter hours of graduate level course work and a thesis pertinent to the area of the elective sequence.

## DEPARTMENTAL REQUIREMENTS FOR THE DEGREE MASTER OF SCIENCE IN MANAGEMENT DATA PROCESSING

1. A candidate for the degree of Master of Science in Management Data Processing must complete satisfactorily either (a) a minimum of 68 quarter hours of graduate level course work or (b) a minimum of 60 quarter hours of graduate level course work and an acceptable thesis.

2. Core course requirements at the graduate level must be successfully completed or validated by advanced credit in each of the following areas:

Computer Science  
Data Processing  
Economics  
Financial Management and Accounting  
Material Management  
Operations Research  
Statistics

## MANAGEMENT

### *Lower Division Courses*

**MN 1500 PERSONAL AFFAIRS (2-0).** The fundamentals of personal estate planning. Included topics: government benefits; life insurance and general insurance; budgeting and banking; borrowing; real estate; securities; wills, trusts, and related legal matters.

### *Upper Division Courses*

**MN 2510 HUMAN BEHAVIOR (4-0).** A survey of some of the important aspects of human behavior that affect performance and satisfaction within an organization. Theories and empirical findings from the behavioral sciences, including motivation, learning, social conditioning, personality, and the measurement of individual behavior patterns.

**MN 2521 GROUP BEHAVIOR AND ORGANIZATION THEORY (4-0).** A survey of theories and empirical findings concerning group effectiveness, leadership, group pressure, and role behavior. Theories and practices of organizational activities such as planning, direction, and control. Examination of organizational processes of particular importance to military and governmental organizations. **PREREQUISITE:** MN 2510.

**MN 2530 INTRODUCTION TO ECONOMICS (4-0).** Economic scarcity and its implications for defense. Comparison of alternative resource allocation systems for an economy. Supply and demand analysis. Debt and financial assets, markets, and intermediaries. The monetary system; international monetary relationships. National income analysis of aggregate output and price level determination and of monetary and fiscal policy.

**MN 2541 MICROECONOMICS (4-0).** A review of supply and demand in individual markets. The theory of consumer choice and theories of the firm in competitive, monopolistic, monopsonistic, and oligopolistic markets. Methodological issues in microeconomic theory. Introductions to illustrative industry analyses and issues in domestic microeconomic policy, international trade, and economic development and growth. An introduction to applications of microeconomic theory to the efficient allocation of resources in national defense. **PREREQUISITE:** MN 2530.

**MN 2542 INTERNATIONAL ECONOMICS (4-0).** Theory of foreign trade, international payments, and exchange rates. Tariffs, quotas, and international trade organizations. Economic growth and development in contrasting econo-

mies. Problems of development in underdeveloped countries. **PREREQUISITE:** MN 2541.

**MN 2550 PRINCIPLES OF ACCOUNTING (4-0).** Study of the basic principles of accounting in business and government. Topics covered include the basic postulates and principles of financial accounting, the accounting cycle, accounting for assets and equities, financial statement content and analysis, manufacturing cost accounting, and the fundamentals of governmental accounting.

**MN 2561 MANAGERIAL CONTROL AND BUDGETING (4-0).** Study of the uses of financial data for planning and control. Specific topics include comprehensive business budgeting, flexible budgets, standard costs, the Navy Industrial Fund, cost-volume analysis, incremental profit analysis, capital budgeting, and the planning-programming-budgeting cycle in DOD. **PREREQUISITE:** MN 2550.

**MN 2900 MANAGEMENT OF HUMAN RESOURCES (4-0).** A survey course in individual and group behavior and the implications thereof for administering the operational objectives of an organization and for the effective management of personnel.

**MN 2960 SURVEY OF MANAGEMENT ACCOUNTING (3-0).** Introduction to the basic concepts and principles of accounting in business and government. Emphasis is placed on uses of accounting data by management in planning, control, and decision making. Applications of automatic data processing to accounting systems are discussed.

**MN 2970 MATERIAL MANAGEMENT (4-0).** Study of the importance of military logistics to our national security and the basic relationships among strategy, tactics, and logistics. Survey of the fundamental elements of the logistics process and the organization in the Navy for logistics administration. Specific topics covered include the planning-programming-budgeting cycle in DOD, budgetary development and execution, and the planning and procurement process, with emphasis on hardware development. The course concludes with a survey of the Navy logistics system, including the Navy Supply System, mobile logistic support forces, joint logistic agencies, and logistics administration at the unit command level.

### *Upper Division or Graduate Courses*

**MN 3110 INDIVIDUAL BEHAVIOR (3-0).** Study of the basic characteristics and determinants of individual behavior. Specific topics covered include personality, motivation, learning, behavior conditioning, and introduction to tests and measurements. Implications for effective administrative practice.

**MN 3121 GROUP AND ORGANIZATIONAL BEHAVIOR (5-0).** Studies of small group behavior and the relationship between the individual and the group. Survey of organization theory, including organizational structure, controls, and systems. Analysis of decision making processes in organizations, of leadership and of factors affecting organizational growth and development. **PREREQUISITES:** MN 3110 and PS 3101.

**MN 3130 MACROECONOMIC THEORY (4-0).** Development of formal equilibrium models to analyze the relationships among aggregate supply and demand, money, output and input price levels, and the implications of fiscal and monetary policy in determining the level of national income. Debt and financial assets, markets, and intermediaries. The monetary system and international monetary relationships.

**MN 3141 MICROECONOMIC THEORY (4-0).** Comparison of alternative resource allocation systems for an economy. Supply and demand analysis: partial and general equilibrium. Introduction to the theory of consumer choice; the theory of the firm in competitive, monopolistic, monopsonistic, and oligopolistic markets. Comparison of calculus and linear programming theories of the firm. Introduction to welfare economics: efficient resource allocation theory. Methodological issues in microeconomic theory. Applications of microeconomic theory to the efficient allocation of resources in national defense. **PREREQUISITE:** MA 2300.

**MN 3150 FINANCIAL ACCOUNTING (4-0).** Study of the basic postulates and principles of financial accounting. Specific topics include the accounting cycle, accounting for assets, equities and capital structure, financial statement analysis, and the uses of financial data for decision making by investors. An introduction to governmental accounting.

**MN 3161 MANAGERIAL ACCOUNTING (4-0).** Study of the principles and practices of cost accounting, including normal overhead rates, job order and process costing, and standard costing. Emphasis is placed upon applications of accounting data to management planning and control. Topics covered include flexible budgets, standard costs and variance analysis, cost-volume analysis, incremental profit analysis, and capital budgeting. **PREREQUISITE:** MN 3150.

**MN 3171 RESOURCE MANAGEMENT FOR DEFENSE (4-0).** Introduction to the Resource Management System of the Department of Defense, with particular emphasis on the systems for the management of capital acquisitions and inventory. Study of the problems of allocating resources for defense and providing material support for major military programs. Specific topics include the planning-programming-budgeting cycle, research and development, material acquisition, and inventory management. **PREREQUISITE:** MN 3130.

**MN 3180 COMPUTERS AND DATA PROCESSING (3-0).** General description of computing and data processing equipment. Instruction in programming language to equip students to make effective use of the School's computing facility. A survey of applications of computers in business and in the military.

**MN 3941 ENGINEERING ECONOMICS (4-0).** An introduction to the basic concepts of microeconomics necessary for decision making: alternative market models; theories of production, with particular attention to technological considerations, production and cost functions; and supply curves. The analysis of investment decision problems. **PREREQUISITE:** A course in probability and statistics.

**MN 3942 INVESTMENT DECISION THEORY (4-0).** Models for private and public investment decision making under conditions of certainty and risk will be developed. Capital investment theory, capital budgeting criteria, sub-optimization, measurement problems, and sensitivity analysis are covered. **PREREQUISITES:** MN 3141, either MN 2960 or MN 3161, and a course in probability and statistics.

#### *Graduate Courses*

**MN 4101 PERSONNEL MANAGEMENT AND LABOR RELATIONS (4-0).** Study of the principles and practices of personnel administration in business and government organizations. A survey of the history, development, and current status of labor-management relations in industry and government. Analysis of the economics of the labor market and the implications of government regulations for wages and labor-management bargaining practices. **PREREQUISITES:** MN 3110 and MN 3141.

**MN 4105 MANAGEMENT POLICY (4-0).** Study and appraisal of a variety of policies requiring the analysis of problems and the formulation of decisions in both business and governmental enterprises. Use of case materials, management games, and other devices as exercises in decision making and executive action under conditions of uncertainty and change. **PREREQUISITES:** MN 3121, MN 3130, MN 3141, MN 3161, MN 3171, MN 3180, and OA 3211.

**MN 4109 DIRECTED STUDY (4-0).** Individual research and study by the student under the supervision of a member of the faculty. Intended primarily to permit interested students to pursue in depth subjects not fully covered in formal class work. **PREREQUISITE:** B average and consent of the instructor.

**MN 4111 SEMINAR IN BEHAVIORAL SCIENCE (4-0).** A combination of directed readings and individual students' research projects presented for discussion in class. Emphasis is placed on empirical analysis of behavioral patterns and relationships. **PREREQUISITE:** MN 3121 and MN 3180.

**MN 4121 SEMINAR IN ORGANIZATION THEORY AND MANAGEMENT PRACTICE (4-0).** A research and discussion approach to the problem areas of organization theory, management practice, and the contributions of various theoretical disciplines to the evolving sciences of management. Particular attention is given to the implications of changes in the environment of organizations, in their internal technology, and in the state of knowledge about human behavior. **PREREQUISITE:** MN 3121.

**MN 4131 ECONOMIC THEORY AND MACROECONOMIC POLICY (4-0).** Further development and application of formal macroeconomic models and of microeconomic theory to analyze the macro and microeconomic consequences of federal spending, transfer payment, taxation, debt management, monetary policies, and wage and price policies. An introduction to econometric and other empirical models of aggregate economic behavior. **PREREQUISITES:** MN 3130, MN 3141 and PS 3101.



**MN 4141 ECONOMIC THEORY AND MICROECONOMIC POLICY (4-0).** Further developments of the concepts of imperfect competition and economic efficiency. Emphasizing applications of theory to analyses of various major U.S. industries and government policies. **PREREQUISITES:** MN 3130 and MN 3141.

**MN 4142 INTERNATIONAL ECONOMIC STUDIES. (4-0).** International monetary relationships and institutions. Comparative advantage and international trade: relationships, institutions, and barriers. Development and growth in alternative economic systems. The problems of underdeveloped economies. **PREREQUISITES:** MN 3130 and MN 3141.

**MN 4145 SYSTEMS ANALYSIS (4-0).** This course will concentrate on the analysis of large scale defense resource allocation problems, using cost-effectiveness models. Topics include: discounting, constrained optimization, estimation problems, and efficiency over time. Systems analysis case studies will be emphasized. **PREREQUISITES:** MN 3121, MN 3130, MN 3141, MN 3161, MN 3171, MN 3180, and OA 3211.

**MN 4151 INTERNAL CONTROL AND AUDITING (4-0).** Study of the fundamental objectives and procedures of internal control in business and government. Examination of the audit function in industry and government. Specific topics include auditing standards, audit reports, sampling techniques, and audits of computer-maintained accounting systems. **PREREQUISITES:** MN 3150, MN 3180, and PS 3101.

**MN 4161 CONTROLLERSHIP (4-0).** Survey of the controllership function in industry and the military. Study of the problems and practices of financial management in large and small organizations. Case studies will be discussed and analyzed in class. **PREREQUISITES:** MN 3141 and MN 3161.

**MN 4171 PROCUREMENT AND CONTRACT ADMINISTRATION (4-0).** Study of the elements of the procurement cycle, including the determination of requirements, contract law, technical and production problems, fiscal controls, facilities, inspections, and terminations. Military procurement regulations are analyzed to determine their impact on efficient military logistic systems. **PREREQUISITE:** MN 3171.

**MN 4181 MANAGEMENT INFORMATION SYSTEMS (4-0).** Study of the "total systems" concept. Development and discussion of an integrated information system, em-

ploying a computer and data processing equipment, used by management for planning and control purposes. Analysis of actual information systems used in industry and the government. **PREREQUISITES:** MN 3150 and MN 3180.

**MN 4182 DATA PROCESSING MANAGEMENT (4-0).** Study of computer systems analysis and design. Management of ADP in the Federal Government, especially in the Department of Defense. Specific topics covered include: feasibility studies, selection, and acquisition of equipment; evaluation of computer hardware and software; installation and effective utilization of ADP equipment; and various types of computer applications. **PREREQUISITE:** Course in computer programming.

**MN 4183 BUSINESS DATA PROCESSING (4-0).** Study of manual, semi-automatic, and automatic systems for the routine processing of data. Specific topics covered include accounting and auditing applications, sequential and random processing with digital computers, and control techniques. Students in small teams will study actual industrial and/or military management situations and recommend appropriate data processing systems. **PREREQUISITES:** Courses in computer programming and probability and statistics.

**MN 4191 QUANTITATIVE DECISION TECHNIQUES (4-0).** A study of the applications of scientific techniques, particularly mathematical and statistical, to management decision making. Consideration of applications of quantitative methods of analysis to complex problems with the aid of computers. **PREREQUISITES:** MN 3180 and OA 3211.

**MN 4931 MATHEMATICAL SEMINAR IN MACROECONOMIC THEORY (4-0).** Analysis and development of linear and nonlinear disaggregated macroeconomic models. Topics selected from equilibrium, dynamic growth equilibrium, and dynamic cyclical and growth disequilibrium models: stability conditions, short and long run resource allocation consequences, and policy implications. **PREREQUISITES:** MN 3130, MN 3141, and consent of instructor.

**MN 4941 MATHEMATICAL SEMINAR IN MICROECONOMIC THEORY (4-0).** Mathematical analysis of microeconomic models. Topics selected from the following: Welfare economics. Theory of efficient resource allocation. Capital theory. Optimal capital accumulation paths. Theory of exchange. Single and multi-period general equilibrium of competitive, monopolistic, and monopsonistic markets; existence and stability conditions. Oligopoly theories. Consumer and producer choice. **PREREQUISITES:** MN 3130, MN 3141, and consent of instructor.

## COMPUTER SCIENCE

### BACHELOR OF SCIENCE WITH MAJOR IN COMPUTER SCIENCE

1. The requirements for a Bachelor of Science with major in Computer Science will include at least 10 hours in upper division mathematics, 10 hours in probability and statistics, 18 hours in computer science, and 4 hours in management.

### MASTER OF SCIENCE IN COMPUTER SCIENCE

1. To obtain the degree, Master of Science in Computer Science, the student must have satisfied the requirements

for the degree Bachelor of Science with major in Computer Science.

2. In addition, the student must successfully complete a minimum of 38 quarter hours of graduate credit distributed as follows:

	<i>Min. Hours</i>
Computer Science	20
Mathematics	8
Operations Analysis	10

3. In addition, the student must successfully complete an acceptable thesis.



*Rear Admiral Armando Zenha de Figueiredo of the Brazilian Navy on an orientation visit to the Computer Facility*

## DEPARTMENT OF ELECTRICAL ENGINEERING

CHARLES HARRY ROTHAUCE, Professor of Electrical Engineering; Chairman (1949)\*; B.E., Johns Hopkins Univ., 1940; D.Eng., 1949.

ROY STANLEY GLASGOW, Dean Emeritus (1949); B.S., Washington Univ., 1918; M.S., Harvard, 1922; E.E., Washington Univ., 1925; D.Sc., (Hon.), Washington Univ., 1961.

GEORGE ROBERT GIET, Professor Emeritus and Distinguished Professor (1925); A.B., Columbia Univ., 1921; E.E., 1923.

RICHARD CARVEL HENSEN WHEELER, Professor Emeritus (1929); B.E., Johns Hopkins Univ., 1923; D.Eng., Rensselaer Polytechnic Institute, 1926.

WILLIAM MALCOLM BAUER, Professor of Electronics (1946); B.S., Northwestern Univ., 1927; E.E., 1928; M.S., Harvard Univ., 1929; D.Sc., 1940.

ORESTES METHODIOUS BAYCURA, Associate Professor of Electrical Engineering (1966); B.S.E.E., Carnegie Institute, 1957; M.S., Univ. of Pittsburgh, 1959; D.Sc., 1963.

JOHN MILLER BOULDRY, Associate Professor of Electrical Engineering (1946); B.S., Northeastern Univ., 1941; M.S., Brown Univ., 1956.

STEPHEN BREIDA, Associate Professor of Electronics (1958); B.S.E.E., Drexel Institute of Technology, 1952; M.S.E.E., Purdue Univ., 1954.

WILLIAM JOHN BRENNER, Assistant Professor of Electrical Engineering (1964); B.S., Merrimack College, 1962; M.S., Stanford Univ., 1964.

SHU-GAR CHAN, Associate Professor of Electrical Engineering (1964); B.S., Univ. of Washington, 1952; M.S., Columbia Univ., 1954; Ph.D., Kansas Univ., 1964.

JESSE GERALD CHANEY, Professor of Electronics (1944); A.B., Southwestern Univ., 1924; A.M., Univ. of Texas, 1930.

PAUL EUGENE COOPER, Professor of Electronics (1946); B.S., Univ. of Texas, 1937; M.S., 1939.

MITCHELL LAVETTE COTTON, Associate Professor of Electronics (1953); B.S., California Institute of Technology, 1948; M.S., Washington Univ., 1952; E.E., Univ. of California at Berkeley, 1954.

JAMES STEVE DEMETRY, Assistant Professor of Electrical Engineering (1960); B.S., Worcester Polytechnic Institute, 1958; M.S., 1960; Ph.D., Naval Postgraduate School, 1964.

FRED WILSON EVANS, JR., Lieutenant, U.S. Naval Reserve; Instructor in Communications; B.S., Univ. of Pittsburgh, 1960.

GERALD DEAN EWING, Associate Professor of Electrical Engineering (1963); A.A., College of Marin, 1955; B.S.E.E., Univ. of California at Berkeley, 1957; M.S.E.E., 1959; E.E., Oregon State Univ., 1962; Ph.D., 1964.

EDWARD MARKHAM GARDNER, Professor of Electrical Engineering (1948); B.S., Univ. of London, 1923; M.S., California Institute of Technology, 1938.

ALEX GERBA, JR., Associate Professor of Electrical Engineering (1959); B.E.E., Univ. of Louisville, 1947; M.S., Univ. of Illinois, 1957.

DAVID BOYSEN HOISINGTON, Professor of Electronics (1947); B.S., Massachusetts Institute of Technology, 1940; M.S., Univ. of Pennsylvania, 1941.

RAYMOND KENNETH HOUSTON, Professor of Electrical Engineering (1946); B.S., Worcester Polytechnic Institute, 1938; M.S., 1939.

ROY MARTIN JOHNSON, JR., Instructor in Electronics (1959); B.S., Univ. of California, 1954; M.S., 1959.

DONALD EVAN KIRK, Assistant Professor of Electrical Engineering (1965); B.S., Worcester Polytechnic Institute, 1959; M.S., Naval Postgraduate School, 1961; Ph.D., Univ. of Illinois, 1964.

CLARENCE FREDERICK KLAMM, JR., Professor of Electronics (1951); B.S., Washington Univ., 1943; M.S., 1948.

GEORGE HEINEMANN MARMONT, Professor of Electronics, (1959); B.S., California Institute of Technology, 1934; Ph.D., 1940.

CARL ERNEST MENNEKEN, Professor of Electronics (1942); B.S., Univ. of Florida, 1932; M.S., Univ. of Michigan, 1936.

ROBERT LEE MILLER, Professor of Electronics (1946); B.Ed., Illinois State Normal Univ., 1936; M.S., Univ. of Illinois, 1941.

RAYMOND PATRICK MURRAY, Associate Professor of Electronics (1947); B.S., Kansas State College, 1937; M.S., Brown Univ., 1953.

GLEN ALLEN MYERS, Associate Professor of Electrical Engineering (1965); B.S.E.E., Univ. of North Dakota, 1955; M.S.E.E., Stanford Univ., 1956; Ph.D., 1965.

HERBERT LEROY MYERS, Assistant Professor of Electrical Engineering (1951); B.S., Univ. of Southern California, 1951.

CHARLES BENJAMIN OLER, Professor of Electrical Engineering (1946); B.S., Univ. of Pennsylvania, 1927; M.S., 1930; D.Eng., Johns Hopkins Univ., 1950.

RUDOLF PANHOLZER, Associate Professor of Electrical Engineering (1964); Dipl. Ing., Technische Hochschule Graz, Austria, 1953; M.S.E.E., Stanford Univ., 1955; D.E., Stanford Univ., 1956; D.Sc., Technische Hochschule Graz, Austria, 1961.



SYDNEY RICHARD PARKER, Professor of Electrical Engineering (1966); B.E.E., City College of New York, 1944; M.S., Stevens Institute of Technology, 1948; Sc.D., 1964.

ORVAL HAROLD POLK, Professor of Electrical Engineering (1945); B.S., Univ. of Colorado, 1927; M.S., Univ. of Arizona, 1933; E.E., Univ. of Colorado, 1940.

GEORGE ANTHONY RAHE, Associate Professor of Electrical Engineering (1965); B.S., Univ. of California at Los Angeles, 1957; M.S., 1959; Ph.D., 1965.

HAROLD LEWIS REICHART, Lieutenant Commander, U.S. Navy; Instructor in Communications; B.S., Naval Academy, 1957; Naval Postgraduate School, 1962.

GEORGE LAWRENCE SACKMAN, Associate Professor of Electrical Engineering (1964); B.M.E., Univ. of Florida, 1954; B.E.E., 1957; M.S.E., 1959; Ph.D., Stanford Univ., 1964.

ABRAHAM SHEINGOLD, Professor of Electronics (1946); B.S., College of the City of New York, 1936; M.S., 1937.

WILLIAM CONLEY SMITH, Professor of Electrical Engineering (1946); B.S., Ohio Univ., 1935; M.E., 1939.

DONALD ALAN STENTZ, Associate Professor of Electronics (1949); B.S., Duke Univ., 1949; M.S., Naval Postgraduate School, 1958.

ROBERT DENNEY STRUM, Associate Professor of Electrical Engineering (1958); B.S., Rose Polytechnic Institute, 1946; M.S., Univ. of Santa Clara, 1964.

FREDERICK WALCUTT Terman, Assistant Professor of Electrical Engineering (1964); B.S., Stanford Univ., 1949; M.S., 1950.

GEORGE JULIUS THALER, Professor of Electrical Engineering (1951); B.E., Johns Hopkins Univ., 1940; D.Eng., 1947.

HAROLD ARTHUR TITUS, Associate Professor of Electronics (1962); B.S., Kansas Univ., 1952; M.S., Stanford Univ., 1957; Ph.D., 1962.

JOHN BENJAMIN TURNER, JR., Associate Professor of Electronics (1955); B.S., Univ. of Arkansas, 1941; M.S., Univ. of California at Berkeley, 1948.

ALLEN EDGAR VIVELL, Professor of Electrical Engineering (1945); B.E., Johns Hopkins Univ., 1927; D.Eng., 1937.

JOHN ROBERT WARD, Associate Professor of Electrical Engineering (1962); B.Sc., Univ. of Sydney, 1949; B.E., 1952; Ph.D., 1958.

MILTON LUDELL WILCOX, Associate Professor of Electrical Engineering (1958); B.S., Michigan State Univ., 1938; M.S., Univ. of Notre Dame, 1956.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

## DEPARTMENTAL REQUIREMENTS FOR DEGREES IN ELECTRICAL ENGINEERING

In addition to meeting the minimum specific academic requirements for these degrees as given below, candidates must also satisfy the general degree requirements as determined by the Academic Council.

### BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

1. Candidates for this degree must generally satisfy the following requirements while in residence at the Naval Postgraduate School except in the case of candidates entering the school with advanced standing, when due allowance will be made for advanced transfer credits.

<i>Discipline</i>	<i>Subject</i>	<i>Approximate Quarter Hrs.</i>
Electrical Engineering	Fields and Circuits	13
	Electronic Devices and Circuits	15
	Communication Theory	4
	Electromagnetic Theory	3
	Energy Conversion	4
	Electronic Computers	4
	Control Theory	4
		<hr/> 47
Mathematics	Calculus, vectors, matrices, series, differential equations and complex variables	12

2. An additional 11 quarter hours are to be taken in upper division courses in Electrical Engineering and 9 quarter hours in areas such as mechanics, dynamics, properties of matter, physical chemistry and thermodynamics. Minor departures from these requirements may be approved by the Department as long as the total number of hours in upper division courses is not reduced.

### MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

A minimum of 40 quarter hours of graduate work shall be required for the degree of Master of Science in Electrical Engineering. At least 30 hours shall be required in Electrical Engineering subjects with ten hours of elective subjects taken in areas other than Electrical Engineering. Normally, these elective hours will be taken in advanced mathematics and physics. An acceptable thesis must be presented.

### BIOLOGY

#### *Upper Division Courses*

BI 2800 FUNDAMENTALS OF BIOLOGY (4-0). The fundamental principles of the living cell covered from a biochemical and biophysical standpoint. Specialization of cell function, as exemplified in certain animal and plant tissues and organs systems. Genetics and its relation to properties of cell nucleus. Related topics, including the evolutionary process.

*Upper Division or Graduate Courses*

BI 3801 ANIMAL PHYSIOLOGY (5-0). A comprehensive course in mammalian physiology, emphasizing human functional aspects. PREREQUISITE: BI 2800.

*Graduate Courses*

BI 4802 RADIATION BIOLOGY (5-0). Fundamental processes of energy transfer from radiation to living matter. Biochemical, physiological and genetic effects of radiation. Methods of experimental radiation biology. PREREQUISITES: BI 3801 and appropriate courses in nuclear physics.

BI 4822 SPECIAL TOPICS IN RADIATION BIOLOGY (2-0). Study of important current topics in radiation biology. PREREQUISITE: Appropriate biological background.

BI 4823 SPECIAL TOPICS IN RADIATION BIOLOGY II (2-0). A continuation of BI 4822. A study of important current topics in radiation biology.

**COMMUNICATIONS***Upper Division Courses*

CO 2111 COMMUNICATIONS ORGANIZATION AND PLANNING (4-0). Organization and functions of the Department of Defense Communication Systems including Command and Control Functions. A study of the National Communications System, Defense Communications Systems and the complete Naval Communications Systems including the Naval Security Group. Individual Missions and/or integration of the systems are analyzed. The Navy Planning System and Development of the Communication Annex are covered.

CO 2112 COMMUNICATIONS ADMINISTRATION AND PROCEDURES I (3-0). Basic organization of unit, including departmental organization. Communications Center functions with emphasis on Message Center handling and/or routing by semi-auto or automatic methods including precedence procedures. Security in general, both physical and crypto, is studied along with the Registered Publications System (RPS).

CO 2113 COMMUNICATIONS ADMINISTRATION AND PROCEDURES II (4-0). A continuation of CO 2112. PREREQUISITE: CO 2112.

CO 2114 COMMUNICATION EQUIPMENT AND SYSTEM APPLICATION I (4-0). A "hardware" course which includes all equipment from basic primary source to sophisticated antennas and transmission lines. Synthesized transmitters and receivers, terminal equipment and microwave relay equipment usage. Frequency compatibility and management and use of propagation prediction charts. Ancillary equipment associated with transmission and/or reception of electromagnetic energy is also studied. Problems and/or solutions associated with compatibility, and installation procedures are studied. The use of Special Communications Systems are covered.

CO 2115 COMMUNICATIONS EQUIPMENT AND SYSTEM APPLICATION II (3-2). A continuation of CO 2114, operation and adjustment of teletypewriter, facsimile, transmitter and receiver equipments in the laboratory. PREREQUISITE: CO 2114.

**COMPUTER SCIENCE***Upper Division Courses*

\*CS 2100 INTRODUCTION TO DIGITAL COMPUTERS (4-0).

\*CS 2110 INTRODUCTION TO COMPUTER PROCESSES (3-0).

*Upper Division or Graduate Courses*

\*CS 3111 COMPUTER ORGANIZATION AND PROGRAMMING (4-0).

CS 3200 LOGICAL DESIGN OF DIGITAL COMPUTERS (4-0). Introduction to the techniques of logical design of computer elements and systems. Boolean algebra, propositional logic, truth tables, simplification of expressions. Applications to switching, circuit elements, design of combinatorial and sequential circuits. Reduction of descriptions of processes to Boolean form. Logic of arithmetic and control units, storage elements. Principles of digital systems design. Existing forms of machine organization. PREREQUISITE: CS 3111 or equivalent.

\*CS 3201 COMPUTER SYSTEMS DESIGN I (4-0).

\*CS 3204 DATA COMMUNICATION (4-0).

CS 3300 INFORMATION STRUCTURES (3-0). Study of information representations and the relationships between the form of representation and processing techniques. Transformations between storage media. Referencing of information as related to the structure of its representation and the implications for the design of the referencing language. Structure of data bases; updating and addition to records; serial and parallel files; storage hierarchies. File management. The role of programs in the data base, their relocation and allocation of storage. PREREQUISITE: Consent of instructor.

CS 3500 MILITARY APPLICATIONS OF COMPUTERS (4-0). Role of computer systems in military operations. Principles and techniques of the design of military information systems. Some technical considerations, e.g., effective data storage and retrieval. Large-scale command and control systems. Strategical and tactical data processing. Systems integration. Real-time sensor-oriented applications, weapons control systems. Data reduction and control. PREREQUISITE: CS 3111 or equivalent.

*Graduate Courses*

\*CS 4112 SYSTEMS PROGRAMMING I (4-0).

\*CS 4113 SYSTEMS PROGRAMMING II (4-0).

\*CS 4200 COMPUTER SYSTEMS DESIGN II (4-0).

\*CS 4310 NON-NUMERICAL INFORMATION PROCESSING (4-0).

\*CS 4900 ADVANCED TOPICS IN COMPUTER SCIENCE (3-0).

\* See listing under Mathematics Department.

### ELECTRICAL ENGINEERING

EE 0951 THESIS SEMINAR (0-1). In these seminar sessions, advanced students will present papers on their thesis work, which will then be discussed by other students and faculty. Some topics may be presented by faculty members.

#### *Upper Division Courses*

EE 2101 PRINCIPLES OF ELECTRICAL ENGINEERING (3-2). Basic concepts of electric and magnetic fields with emphasis on electrical engineering applications: the circuit concept;  $v$ - $i$  relations; Kirchhoff's voltage and current laws; power and energy. PREREQUISITE: Integral Calculus (may be concurrent).

EE 2102 CIRCUIT ANALYSIS (4-2). Solution of network equations using basic Laplace transform methods; transfer function; sinusoidal steady state analysis including phasor methods, frequency response including resonance, network theorems, two-port parameters, balanced polyphase circuits, and coupled circuits. PREREQUISITE: EE 2101, Differential Equations (may be concurrent).

EE 2201 GENERAL ELECTRONICS (4-2). A one-term survey course, for non-electrical engineering curricula, with emphasis on the general operational characteristics of representative electronic devices. Topics included are: physical processes in common devices; current-voltage relations of diodes and active devices; basic electronic circuits. PREREQUISITE: EE 2102.

EE 2211 ELECTRONIC ENGINEERING FUNDAMENTALS I (4-2). A general introduction to electronic devices, circuits and systems is followed by the consideration of the electronic properties of matter, conduction and emission processes, diodes and diode circuits, multi-terminal control devices, amplifier characteristics, and equivalent-circuit representations and analysis of linear amplifiers. PREREQUISITE: EE 2101.

EE 2212 ELECTRONIC ENGINEERING FUNDAMENTALS II (4-3). The topics studied include untuned small-signal amplifiers, feedback in amplifiers, direct-coupled and operational amplifiers, small-signal tuned amplifiers, electronic power supplies, untuned and tuned power amplifiers. PREREQUISITE: EE 2211.

EE 2213 ELECTRONIC COMMUNICATIONS CIRCUITS (4-3). The topics studied include sine-wave oscillators, reactance modulators, frequency-modulated and amplitude-modulated transmitters, frequency converters, superhetrodyne receivers, special band-pass amplifiers, detectors, auto-

matic gain control, and the production and detection of SSB signals. PREREQUISITE: EE 2212.

EE 2214 ELECTRONIC PULSE AND DIGITAL CIRCUITS (4-3). The topics studied include basic waveform characteristics and shaping techniques, wide-band linear amplifiers, characteristics of electronic switching devices, clipping, clamping and switching circuits, multivibrator and trigger circuits, time-base generators, logic circuits, counting and timing circuits. PREREQUISITE: EE 2212.

EE 2215 SPECIAL ELECTRONIC DEVICES (4-2). The topics studied include charged-particle dynamics, microwave tubes, parametric amplifiers, non-reciprocal microwave devices, quantum-electronic devices, microelectronics and other current device developments. PREREQUISITES: EE 2213 and EE 2214.

EE 2221 ELECTRONICS FUNDAMENTALS I (3-2). An introduction to electronic devices, circuits and systems is followed by the consideration of basic electrical circuit concepts, electronic conduction and emission processes, physical process in electronic devices and operational properties of diodes and amplifier devices.

EE 2222 ELECTRONICS FUNDAMENTALS II (4-3). A terminating continuation of EE 2221. Included topics are linear amplifier analysis, feedback techniques, tuned amplifiers, power amplifiers, oscillators, electronic power supplies, communications circuits and selected electronic systems considerations. PREREQUISITE: EE 2221.

EE 2223 INTERMEDIATE ELECTRONICS (3-3). A continuation of EE 2221 for students who will take EE 2224. Included topics are linear amplifier analysis, feedback techniques, tuned amplifiers, power amplifiers, and electronic power supplies. PREREQUISITE: EE 2221.

EE 2224 COMMUNICATION ELECTRONICS (4-3). The topics studied include sine-wave oscillators, basic modulation techniques for information transmission, frequency spectrum of modulated waves, generation of AM and FM waves, communication transmitters, detectors, frequency conversion, communication receivers, SSB systems and multiplex systems. PREREQUISITE: EE 2223.

EE 2225 PULSE ELECTRONICS (3-3). The topics studied include linear wave-shaping circuits, linear amplification of pulse signals, device switching characteristics, clipping and clamping circuits, multivibrators, sweep generators, logic and counting circuits, system application of pulse and waveforming techniques. PREREQUISITE: EE 2222 or EE 2223.

EE 2231 ELECTRONICS I (Nuclear) (3-3). This is the first of two courses designed to give the Nuclear Engineering student an appreciation of electronic equipment used in this science. Topics are: Steady state circuit analysis, transient concepts, and the basic theory of vacuum and semiconductor diodes, control type tubes, and transistors. PREREQUISITES: Mathematics through calculus.



EE 2232 ELECTRONICS II (Nuclear) (3-3). This course considers vacuum tube and transistor circuits, such as power supplies, voltage amplifiers, feedback circuits, pulse amplifiers, and pulse shaping circuits. Basic concepts are then applied to a variety of special circuits, including: integral and differential discriminators; coincidence and anti-coincidence circuits, count-rate meters, and scalars. PREREQUISITE: EE 2231.

EE 2311 PRINCIPLES OF ENERGY CONVERSION (3-2). An introduction to the principles of energy conversion. Topics introduced are thermoelectric, thermionic, photovoltaic, electrochemical, electromagnetic, gaseous conduction leading to MHD concepts and other basic methods of energy conversion. PREREQUISITES: EE 2102, a course in Modern and/or Solid State Physics.

EE 2312 ELECTROMAGNETIC MACHINES (3-4). The model oriented approach to the analysis of rotating machines and amplifiers is utilized to obtain their dynamic and steady state characteristics. D-C and A-C motors, generators and control machines are analyzed. PREREQUISITES: EE, 2311, EE 3103.

EE 2323 TRANSDUCERS (3-2). The principles of energy conversion are applied to transducers, with emphasis on those that produce electrical or mechanical signals. Presented are photoelectric, magnetostrictive, piezoelectric, electrostatic, and electromagnetic devices. PREREQUISITE: EE 2311.

EE 2332 ELECTRIC MACHINES (3-3). This course is intended for the Mechanical Engineering curriculum. Principles of electromechanical energy conversion are presented in sufficient depth to provide understanding of the electric machines characteristics. A-C and D-C motors and generators are covered with emphasis on the steady-state performance. However, some dynamics will be studied. Polyphase circuit analysis is included. PREREQUISITE: EE 2102 or equivalent.

EE 2431 INTRODUCTION TO RADAR (3-2). A one-quarter course designed for students not majoring in electronics. The course includes a study of search, fire-control, and radar-guidance systems with particular emphasis on pulse, FM, doppler, and mono-pulse systems. PREREQUISITES: EE 2214 and EE 2612.

EE 2611 ELECTROMAGNETIC FIELDS (3-0). An introduction to electromagnetic field theory. Following a review of static electric and magnetic fields, Maxwell's equations are presented for time-varying fields. Additional topics are skin effect, plane wave propagation, and reflection of waves. PREREQUISITE: EE 2102.

EE 2612 TRANSMISSION OF ELECTROMAGNETIC ENERGY (3-1). A study of radio-frequency transmission lines, waveguides, and related components. Classical transmission line theory is developed and applied to practical problems. The principles of rectangular and cylindrical waveguides, cavity resonators, and various microwave devices are covered. PREREQUISITE: EE 2611.

EE 2711 ELECTRICAL AND ELECTRONIC MEASUREMENTS (3-3). A study of methods and techniques for the measurement of electrical quantities such as voltage, current, power, frequency, phase angle, circuit parameters, fields, etc., and including statistical analysis of experimental data with emphasis on precision and accuracy. PREREQUISITE: EE 2102.

EE 2811 DIGITAL MACHINES (2-0). A study of number systems, machine language, and the organization of simple digital machines. Some current machines are discussed in order to illustrate the organization of and signal flow through a typical digital machine. PREREQUISITE: MA 2232 (may be taken concurrently).

EE 2832 COMPUTER SYSTEMS TECHNOLOGY (3-2). A course, primarily for the student not specializing in data processing, in the fundamental methods, concepts, and techniques underlying modern naval computer-oriented systems, such as NTDS and the OPCONCEN. Formulation of operational requirements. Evaluation of engineering techniques. Programming methods for large scale command-control systems. Differing requirements of tactical versus strategic problems. The laboratory work provides the opportunity for the student to gain familiarity with methods for implementing user and command functions in a typical system environment.

#### *Upper Division or Graduate Courses*

EE 3103 LINEAR SYSTEMS ANALYSIS (3-3). Applications of Fourier series and Fourier transform methods; convolution; state-variable formulation and solution; other operational concepts; flow graphs; simulation of linear systems on the analog computer. PREREQUISITE: EE 2102, Complex Variable Theory (may be concurrent).

EE 3114 COMMUNICATION THEORY I (4-0). In this introductory course the following concepts and their mathematical formulations are presented: power spectral density; matched filters; sampling; pulse encoding methods; frequency and time multiplexing; amplitude, frequency and phase modulation. In addition, a comparison of modulation methods is presented. PREREQUISITE: EE 3103.

EE 3116 COMMUNICATION THEORY II (3-2). A continuation of EE 3114. The concept of information measure (entropy) is introduced and its significance for communication systems is discussed. Noise sources and their measurement are treated. Statistical methods for handling noise and random signals are presented, followed by a study of detection problems in radar and pulse transmission systems. Correlation functions and their applications to communication systems are introduced. PREREQUISITES: EE 3114, PS 2111.

EE 3215 ADVANCED ELECTRONIC DEVICES (4-2). The topics studied include particle dynamics, electron beam-forming focusing techniques, microwave tubes, negative resistance and variable-reactance devices, non-reciprocal microwave devices, quantum-electronic devices, microelectronic and other current device developments. PREREQUISITES: EE 2213 and EE 2214.

EE 3261 NONLINEAR MAGNETIC DEVICES (3-3). An introduction to the use of the saturable reactors as a non-linear circuit element. Pulse, storage, counting circuits as used in data processing and digital computer technology, as well as power modulation applications are considered. Piecewise linear analysis techniques are used to develop the theory of magnetic amplifiers. The transfer function of the amplifier with and without feedback is derived. PREREQUISITES: EE 2212 and EE 3103.

EE 3262 ELECTRONIC CONTROL AND MEASUREMENT (3-3). Analysis and design of electronic circuits of control, measurement, data transmission and processing. Topics included are: vacuum-tube voltmeters, DC amplifiers, pulse-shaping and switching circuits, oscillators and time-base generators, counting and time-interval measuring circuits, frequency measurement and control circuits, motor-speed and generator-voltage control systems. PREREQUISITES: EE 2212 and EE 3103.

EE 3263 SOLID-STATE CIRCUIT DESIGN (3-3). Design and analysis of 2-stage direct-coupled transistor amplifiers—biasing and AC performance; DC amplifiers; wide band amplifiers; tuned IF, RF small signal and power amplifiers; oscillators; FET circuits; Triac devices and circuits for power control; integrated circuits. PREREQUISITE: EE 2212.

EE 3264 ADVANCED THEORY OF SEMICONDUCTOR DEVICES (4-0). The application of solid state physics to the analysis and characterization of semiconductor diodes, transistors, and integrated circuits will be studied. Attention will be given to the relationship between the internal physical processes in these devices and their responses to large, high-frequency and transient signals. PREREQUISITES: EE 3215 or EE 2215 and PH 3741 or equivalent.

EE 3313 MARINE ELECTRICAL ANALYSIS AND DESIGN (3-2). Design principles of electric machines are studied. Symmetrical components are presented and applications are made in the short circuit analysis of a portion of a ship's power distribution system. A computer study of a static excitation system is made. PREREQUISITES: EE 2312 and EE 3411.

EE 3411 CONTROL SYSTEMS (3-3). (May be taught as AE 3341 or CH 3701) Introduction to the analysis and design of linear feedback control systems by means of s-plane and frequency response methods. Analysis using state variables; design using frequency and time domain performance indices is discussed. Laboratory work includes simulation using analog and digital computers: testing and evaluation of physical systems. PREREQUISITES: EE 2102 and MA 2232 or their equivalent.

EE 3412 NON-LINEAR AND SAMPLED SYSTEMS (3-3). Phase plane and describing function techniques are applied to the analysis of non-linear systems. Sampled systems are studied using state space and Z-transform methods. Laboratory work includes analog and digital simulation, analysis of a relay servomechanism, and application of digital control to a system. PREREQUISITE: EE 3411.

EE 3422 MODERN COMMUNICATIONS (3-2). A study of modern communications trends, with emphasis on theoretical study of current and proposed systems. The topics covered include multiplex systems, coding, and pseudo-random noise modulation systems. PREREQUISITE: EE 3116 or EE 4571.

EE 3432 PULSE RADAR (3-2). The basic special circuits used in pulse radar are discussed and integrated into a complete radar system. These circuits include pulse modulators, display systems, transmitters, duplexing systems, and receivers. The radar range equation is developed, and pulse compression techniques for giving increased range with good range resolution are discussed. Automatic radar tracking systems are introduced. PREREQUISITES: EE 3114, EE 2215 and EE 2612.

EE 3455 SONAR SYSTEMS (3-2). A study of sonar theory including the active and passive systems. The course starts with a study of the basic characteristics of the transmission medium and continues with a study of the problems and limitations of operating an acoustic system in this environment. Modern systems and projects are included in the study. PREREQUISITE: EE 2213, SECRET Clearance.

EE 3471 GUIDANCE AND NAVIGATION (3-0). A study of the principles underlying systems of guidance and navigation. The principal topics are: radio, radar, infra-red inertial and celestial techniques. PREREQUISITES: Mechanics, EE 2214, and EE 3411.

EE 3481 RADAR AND ECM (3-2). Continuous wave, frequency modulation, MTI, AMTI, and pulse doppler techniques used in modern military radar systems are discussed. Electronic countermeasure and counter-countermeasure (ECM and ECCM) techniques are discussed with particular application to radar. ECM topics covered include signal intercept, signal analysis, masking jammers, deception jammers, confusion reflectors, target masking, and anti-jamming techniques. PREREQUISITES: EE 3432 and SECRET Clearance.

EE 3482 COMMUNICATIONS ECM (3-2). A study of communications signals, and the characteristics of devices used for detecting and interfering with these signals and systems. The course includes both active and passive countermeasures methods and techniques for both radio frequency and underwater acoustic spectrums. Emphasis is placed on modern methods of evaluation of a signal system and its environment. PREREQUISITE: EE 3422, SECRET Clearance.

EE 3498 DYNAMIC SYSTEMS ANALYSIS (3-3). The following topics are considered: state-variable formulation and solution; flowgraphs; analysis of linear feedback systems; simulation of linear systems; testing of physical systems. PREREQUISITE: EE 2102.

EE 3621 ELECTROMAGNETICS I (3-1). Classical transmission line theory is developed and illustrated in laboratory exercises. The theory of static electric and magnetic fields is presented, and solutions of boundary value prob-



lems are obtained by means of scalar and vector potentials. PREREQUISITES: Vector Analysis, Partial Differential Equations, and EE 2102.

EE 3622 ELECTROMAGNETICS II (3-0). The time-varying Maxwell equations and general boundary conditions are presented. Solutions to the wave equation in unbounded regions are studied. Maxwell's equations are applied to systems of guided waves and cavity resonators. PREREQUISITES: EE 3621 and EE 3103.

EE 3631 ANTENNAS AND PROPAGATION (3-2). An engineering course covering the major classes of antennas for communications and radar followed by a study of the properties of the atmosphere and its effect on the propagation of surface space, and sky waves. While essentially stressing engineering, the course applies to practical systems the field theory presented in earlier courses. PREREQUISITES: EE 2612 or EE 3622.

EE 3812 LOGICAL DESIGN AND CIRCUITRY (3-2). Introduction to Boolean algebra. Symbolic logic and the analysis of basic logical circuits; qualitative description of basic electronic and semiconductor devices; construction of computer circuits using tubes, transistors, etc. Models for switching networks, synthesis of combinational and sequential switching circuits. Logical design of arithmetic and control elements. Memory devices, conventional and exotic. Machine-aided logical design. PREREQUISITE: EE 2811.

EE 3822 DIGITAL COMPUTER SYSTEMS (3-3). This course investigates the role and functions of digital and hybrid computing machines and their engineering applications in such fields as signal processing and system control. Digital display techniques are applied. The principle features of such computerized systems are studied. PREREQUISITE: EE 2811.

#### *Graduate Courses*

EE 4121 ADVANCED NETWORK THEORY I (3-2). Topology; state-variable formulation for nonlinear, time-varying networks; concepts and tests for passivity, activity, causality; driving-point synthesis; introduction to transfer function synthesis. PREREQUISITE: EE 3103.

EE 4122 ADVANCED NETWORK THEORY II (3-2). Continuation of transfer function synthesis; n-port synthesis; scattering matrix; the approximation problem. PREREQUISITE: EE 4121.

EE 4123 ADVANCED NETWORK THEORY III (3-2). Topics selected from the following: active network synthesis; topological synthesis; time-domain synthesis; computer methods in network synthesis. PREREQUISITE: EE 4122.

EE 4125 OPERATIONAL METHODS FOR LINEAR SYSTEMS (3-1). A study of the mathematical methods employed in the design and analysis of linear systems. Topics include: basic concepts of systems analysis; analytic functions of a complex variable; the Fourier integral and Fourier transform; bilateral Laplace transform; Hilbert transforms. PREREQUISITE: EE 3103.

EE 4414 STATISTICAL CONTROL THEORY (3-0). Statistical and probabilistic concepts are applied to the development of optimal methods for estimation, prediction, and identification. These methods are applied to the stochastic control problem. PREREQUISITES: EE 3412 and PS 3112.

EE 4415 ALGEBRAIC METHODS IN CONTROL THEORY (3-0). This course treats advanced concepts in root locus theory including graphical and analytic (algebraic) design of compensation. Extension is made to two parameter analysis and design. The Mitrovic-Siljak relationships are developed, leading to the coefficient plane and parameter plane methods. Stability analysis, adjustment, design and synthesis using parameter plane methods are treated in detail. Extensions to multiparameter problems are discussed. PREREQUISITE: EE 3411.

EE 4416 TOPICS IN MODERN CONTROL THEORY (3-0). A course intended to acquaint the student with recent developments in control as found in the research publications of the profession. Topics are selected at the discretion of the instructor and may include such subjects as: Adaptive Systems, Digital and Hybrid Simulation, Finite State Automata, Learning Systems, Lyapunov Methods, Popov Stability, Sensitivity, etc. PREREQUISITES: EE 4414, EE 4415, and EE 4417, or consent of the Instructor.

EE 4417 OPTIMAL CONTROL (3-0). The optimal control problem is treated using the calculus of variations, Pontryagin's maximum principle, and dynamic programming. Optimal pursuit-evasion strategies are considered. PREREQUISITE: EE 3412.

EE 4433 RADAR SYSTEMS (3-2). The radar range equation is developed in a form including signal integration, the effects of cross-section fluctuations and system and propagation losses. Modern techniques discussed include pulse compression, frequency modulated radar, MTI, AMTI, pulse doppler systems, monopulse tracking systems, and multiple-unit steerable array radars. Laboratory sessions deal with basic pulse radar system from which the advanced techniques have developed. PREREQUISITES: EE 3622.

EE 4451 SONAR SYSTEMS ENGINEERING (3-2). A study of the theory and engineering practices of active and passive sonar systems. A study is made of the problems and limitations of underwater acoustic systems with emphasis placed on the new developments and projects designed to improve these systems. The objective of the course is to determine how the design and engineering of a sonar system is limited by the characteristics of the transmission medium. PREREQUISITE: PH 3452, SECRET Clearance.

EE 4461 SYSTEMS ENGINEERING (3-1). An introduction to the engineering of large scale systems. The primary aim of this course is to increase the student's awareness of the complex interactions of various disciplines and the main recurring problems in systems engineering. Examples from large scale military weapons systems will be studied. PREREQUISITES: EE 4571 and EE 3412.



EE 4473 MISSILE GUIDANCE SYSTEMS (3-0). Fundamentals of missile guidance systems: radio, radar, infra-red, inertial and celestial techniques. PREREQUISITES: EE 3412, EE 4433, and Mechanics.

EE 4481 ELECTRONIC COUNTERMEASURES (3-2). Active and passive countermeasure techniques are discussed including signal interception and analysis, masking jammers, deception techniques, confusion reflectors, target masking, anti-jamming techniques, communications jamming, infrared countermeasures, and underwater acoustic countermeasures. PREREQUISITES: EE 4433, and SECRET Clearance.

EE 4491 NUCLEAR REACTOR CONTROL SYSTEMS (3-0). The non-linear reactor kinetic equations are analyzed under controlled and accidental input conditions. The small-signal input method is used and the zero-power and power-to-reactivity feedback transfer functions are obtained. The requirements for stable and accurate operation of automatic flux control are established using linear feedback control theory. Digital computer methods of simulating the non-linear system are used to check on the validity of the linear theory. Modern control theory application to nuclear reactor systems is introduced. PREREQUISITE: EE 3412.

EE 4541 SIGNAL PROCESSING (3-1). Applications of statistical decision theory to the detection of signals in noise. Ambiguity diagrams for signal detection and parameter estimation; signal design. Applications to antenna and transducer arrays. Signal processing in detection and tracking systems. PREREQUISITE: EE 4571.

EE 4571 STATISTICAL COMMUNICATION THEORY (3-2). This course is a more advanced sequel to EE 3114 than EE 3116. Basic concepts of information theory are introduced and their significance for communication systems are discussed. A study of noise sources and a mathematical treatment of noise and random signals, based on statistical methods, are presented. Transmission of such signals through linear and non-linear networks is analyzed. Statistical decision theory applications to signal detection and interpretation are illustrated by selected problems. PREREQUISITES: EE 3114 and PS 3112.

EE 4581 INFORMATION THEORY (3-1). Concepts of information measure for discrete and continuous signals. Fundamental theorems relating to channel capacity and coding; coding methods. Effects of noise on information transmission. Selected applications of the theory to systems. PREREQUISITE: EE 4571.

EE 4631 ANTENNA ENGINEERING (3-2). This course is intended to make the student familiar with the more common types of antennas and feed systems. The attack is essentially an engineering approach, applying to practical systems the mathematics and field theory presented in earlier courses. The laboratory is directed to the measurement of field intensities, antenna patterns, input impedance and feed systems. PREREQUISITES: EE 2612 or EE 3622.

EE 4652 MICROWAVE CIRCUITS AND MEASUREMENTS (3-2). A study of microwave components as circuit elements. Topics to be studied will include: waveguides as transmission lines, waveguide impedance concepts, matrix formulation for obstacles in waveguides, and resonant cavities as microwave circuit elements. PREREQUISITE: EE 3622.

EE 4671 THEORY OF PROPAGATION (3-0). Properties of the atmosphere and its effect on the propagation of surface, space, and sky waves. Additional topics include: coverage prediction, frequency selection, noise, and tropospheric and ionospheric scatter. PREREQUISITE: EE 2612 or EE 3622.

EE 4823 ADVANCED DIGITAL COMPUTER SYSTEMS (3-1). Selected advanced topics in digital system engineering. Concepts of shared-file processors, real time computing, data collection, multitask processors. State-of-the-art utilization of logical components, machine organization, problem-oriented languages, man-machine interfaces. Representative case studies in such areas as: pattern classification, electronic design automation, information retrieval, weapons control, war-gaming. PREREQUISITE: EE 3822.

EE 4911 INFORMATION PROCESSING SEMINAR (0-2). Discussion and reports on related topics of current interest in the field of information processing.

## ENGINEERING SCIENCE

*Approximate  
Quarter Hrs.***BACHELOR OF SCIENCE IN ENGINEERING SCIENCE**

1. The following are the minimum requirements for the degree Bachelor of Science in Engineering Science.

2. The degree in Engineering Science requires a minimum of 100 quarter hours in Engineering and Science of which at least 50 hours must be at the upper division level.

3. The following specific requirements must be met. Areas marked with an asterisk must include laboratory work:

a. Mathematics through calculus	17
b. Chemistry and Material Science*	15
c. Physics*	16
d. Electrical Engineering*	14
e. Probability and Statistics	3
f. Computers and Data Processing	4
g. Thermodynamics	4
h. Space Dynamics	4
i. Electives in Engineering and Science	23
	<hr/> 100

Electives will be chosen from courses in Mechanical Engineering, Electrical Engineering, Operations Analysis, Probability and Statistics, Computer Science, Oceanography, Meteorology, Mathematics, Chemistry or Physics.



*Dean Rinehart presenting the Mewborn Student Research Award to Lieutenant Commander Robert K. Sparkes, Royal Canadian Navy*

## DEPARTMENT OF GOVERNMENT AND HUMANITIES

EMMETT FRANCIS O'NEIL, Professor of Government and Humanities; Chairman (1958)\*; A.B., Harvard Univ., 1931; M.A., Univ. of Michigan, 1932; Ph.D., 1941.

LOFTUR L. BJARNASON, Professor of Literature (1958); A.B., Univ. of Utah, 1934; A.M., Harvard Univ., 1939; Ph.D., Stanford Univ., 1951.

WILLIAM CLAYTON BOGGESE, Associate Professor of Speech (1956); B.S., Univ. of Southern California, 1953; M.S., 1954.

RUSSELL BRANSON BOMBERGER, Associate Professor of Psychology (1958); B.S., Temple Univ., 1955; M.A., Univ. of Iowa, 1956; M.S., Univ. of Southern California, 1960; M.A., Univ. of Iowa, 1961, Ph.D., 1962.

ERLING ARTHUR ERICKSON, Assistant Professor of History (1966); B.A., Luther College, 1956; M.A., Univ. of North Dakota, 1959; Ph.D., Univ. of Iowa, 1966.

BARBARA LOUISE GABEL, Associate Professor of English (1967); A.B., Dickinson College, 1945; A.M., Peabody College, 1946; Ph.D., Univ. of North Carolina, 1954.

LLOYD WILLIAM GARRISON, Commander, U.S. Navy; Assistant Professor of Political Science; B.A., Santa Barbara State College, 1941; M.A., Univ. of Hawaii, 1965.

BOYD FRANCIS HUFF, Professor of Government and History (1958); B.A., Univ. of Washington, 1938; M.A., Brown Univ., 1941; Ph.D., Univ. of California, 1955.

ROBERT LEONARD JACOBS, Lieutenant (junior grade), U.S. Naval Reserve; Instructor in Political Science; A.B., North Texas State Univ., 1962; M.A., Pennsylvania State Univ., 1964.

BURTON MACLYNN SMITH, Associate Professor of Speech (1955); B.A., Univ. of Wisconsin, 1936; M.A., 1937.

RUSSEL HENRY STOLFI, Assistant Professor of History (1966); B.S., Stanford Univ., 1954; M.A., 1964; Ph.D., 1966.

FRANK M. TETI, Assistant Professor of Political Science (1966); B.A., Los Angeles State College, 1960; M.A., 1962; Ph.D., Maxwell School of Syracuse Univ., 1966.

## DEPARTMENTAL REQUIREMENTS FOR THE DEGREE BACHELOR OF ARTS WITH MAJOR IN GOVERNMENT (INTERNATIONAL RELATIONS)

A minimum of 40 quarter hours of upper division (2000 level) courses in Government, including the following:

*Quarter Hrs.*

- |   |     |
|---|-----|
| a. <i>B.A. Required Courses:</i> GV 2160,<br>GV 2161, GV 2163 and GV 2164   | 14  |
| b. <i>Major Electives:</i> Three courses each from<br>the fields of International Relations<br>and Comparative Government | 24  |
| c. One elective from the field of<br>American Government  | 3-4 |

## DEPARTMENT OF GOVERNMENT AND HUMANITIES ENGLISH

### *Upper Division Courses*

EN 2010 ADVANCED WRITING (3-0). Intensive writing experience in the four classical disciplines—description, narration, exposition, argumentation, with special emphasis on logic and informative writing. PREREQUISITE: Freshman English or permission of Chairman of Department.

EN 2011 TECHNICAL WRITING (3-0). The writing of technical papers.

### *Upper Division or Graduate Courses*

EN 3310 RESEARCH METHODS (2-0). A study of principles and practices of research writing applied to the preparation, analysis, and evaluation of reports, scientific papers, theses, and dissertations. PREREQUISITE: Graduate standing or permission of Chairman of Department.

## GEOGRAPHY

### *Upper Division Courses*

GY 2291 POLITICAL GEOGRAPHY (4-0). A study of world areas, regions, and countries, with emphasis on the location and political significance of terrain features.

## GOVERNMENT

### *Lower Division Courses*

GV 1060 U.S. GOVERNMENT (3-0). American political institutions and processes, the Constitution, parties, interest groups, elections, and voting behavior, with special emphasis on current issues and problems.

GV 1368 AMERICAN LIFE AND INSTITUTIONS (3-0). American political institutions and the political, social, economic, and cultural aspects of American life. Open only to Allied Officers.

### *Upper Division Courses*

GV 2061 NATIONAL SECURITY (3-0). Analysis of the national defense structure, the formulation and execution of

\* The year of joining the Postgraduate School Faculty is in parentheses.



strategic concepts; relationships of weapons systems; economic factors and political potentials and requirements to the achievement of national goals. PREREQUISITE: GV 1060.

GV 2160 COMPARATIVE GOVERNMENT (4-0). An analytical and comparative study of the form and functioning of the major types of contemporary government with emphasis on the policy-making process. PREREQUISITE: GV 1060.

GV 2161 INTRODUCTION TO INTERNATIONAL RELATIONS (3-0). The relations of nations, including a consideration of the factors of national power and study of international interests, and organizations.

GV 2163 POLITICAL THOUGHT (4-0). The principal political philosophers; Plato to the French Revolution.

GV 2164 COMPARATIVE IDEOLOGIES (3-0). The major ideological forces in contemporary World Affairs and the developmental patterns of Democracy, Socialism, Communism, and Fascism. PREREQUISITE: GV 2163.

GV 2262 THEORY AND PRACTICE OF INTERNATIONAL POLITICS (4-0). A theoretical approach to the study of international relations and an analysis of the factors, organization, strategies, and techniques of international politics. PREREQUISITES: HI 2130; GV 2161.

GV 2263 GOVERNMENT AND POLITICS OF THE MIDDLE EAST (4-0). A study of political, economic, social, cultural and strategic aspects of the contemporary Middle East and its role in international relations.

GV 2264 GOVERNMENT AND POLITICS OF THE SOVIET UNION (4-0). The structure and function of the Soviet government and the Communist Party in decision-making and planning in the Soviet Union. PREREQUISITE: HI 2130.

GV 2265 GOVERNMENT AND POLITICS OF SOUTHEAST ASIA (4-0). The international, internal, and military problems of the southeast Asian states.

GV 2266 GOVERNMENT AND POLITICS OF EAST ASIA (4-0). The international, internal, and military problems of China, Japan, and Korea.

GV 2268 RECENT EUROPEAN DIPLOMACY (1950-Present) (4-0). Foreign affairs of the major European States from 1950 to the present. PREREQUISITE: HI 2030.

GV 2270 AMERICAN POLITICAL THOUGHT (3-0). A study of American political thought from the colonial period to the present. PREREQUISITES: GV 1060, 2163; HI 2032, HI 2131.

GV 2271 AMERICAN CONSTITUTIONAL ISSUES (3-0). The United States Constitution and its development,

with emphasis on leading constitutional issues such as federalism, civil-military relations, public-private interests and civil rights. PREREQUISITES: GV 1060; HI 2032, 2131.

GV 2272 AMERICAN TRADITIONS AND IDEALS (4-0). The traditions, ideals and values of our civilization and the role of the military in implementing the image of America in the world. PREREQUISITES: HI 2032, HI 2131; GV 2163, GV 2270.

GV 2273 RECENT AMERICAN DIPLOMACY (4-0). An analysis of the major problems of United States foreign relations in Europe, Latin America and the Far East from 1898 to the present. PREREQUISITES: HI 2030, HI 2032.

GV 2274 AMERICAN PARTY POLITICS (3-0). The nature and function of political parties; origin, development, structure, internal management and control; relation of parties and pressure groups to legislation and administration; analysis of voting behavior and participation in politics. PREREQUISITE: GV 1060.

GV 2275 INTERNATIONAL LAW (3-0). A survey of the basic principles of international law with emphasis on jurisdiction and the rules of warfare. Case and problem discussions.

GV 2279 DIRECTED STUDIES IN GOVERNMENT (Credit Open). Independent study in government in subjects in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department.

GV 2381 AVIATION LAW (1-0). A study of the privileged status of the Aircraft Accident Investigation designed especially for the Aviation Safety Officer Program.

## HISTORY

### *Upper Division Courses*

HI 2030 EUROPEAN HISTORY (1914-1950) (3-0). Foreign and domestic affairs of the major European states from the first world war through the immediate aftermath of the second world war.

HI 2032 U.S. HISTORY (1865-present) (3-0). A survey of the political, economic and social history of the United States from Reconstruction to the present.

HI 2130 EUROPEAN HISTORY (1815-1914) (3-0). Foreign and domestic affairs of the major European states from the Congress of Vienna to the outbreak of the first world war.

HI 2131 U.S. HISTORY (1763-1865) (3-0). A survey of the political, economic and social history of the United States from the American Revolution to the end of the Civil War.

HI 2239 DIRECTED STUDIES IN HISTORY (Credit Open). Independent study in history in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department.

**LITERATURE***Lower Division Courses*

LT 1040 APPRECIATION OF LITERATURE (3-0). A study of selected works of literature. The selection is intended to enhance the student's understanding and appreciation of literature as the most commonly used vehicle in expressing the aspirations, the hopes, and the enduring problems of mankind.

*Upper Division Courses*

LT 2241 MASTERPIECES OF AMERICAN LITERATURE (3-0). A study of selected works of American literature as they reflect the cultural, political, and sociological aspirations of the American people. PREREQUISITE: LT 1040 or permission of the Chairman of Department.

LT 2242 MASTERPIECES OF BRITISH LITERATURE (3-0). A study of British literature with its cultural and historical implications. A modified survey approach is used, but selected works and authors are studied in some depth. PREREQUISITE: Same as for LT 2241.

LT 2243 MASTERPIECES OF EUROPEAN LITERATURE (3-0). A study of selected masterpieces of European literature. An effort is made to impress the student with the continuity of the Western European intellectual heritage. PREREQUISITE: LT 1040 or permission of Chairman of the Department.

LT 2244 MASTERPIECES OF WORLD LITERATURE (3-0). A study of selected masterpieces of world literature. The selection will vary, depending upon the needs and interests of the students. PREREQUISITES: LT 1040, plus at least one of the following: LT 2241, 2242, 2243.

**PSYCHOLOGY***Upper Division Courses*

PY 2050 GENERAL PSYCHOLOGY (3-0). A study of principles of rational and emotional processes in human thought and action.

PY 2251 APPLIED SOCIAL PSYCHOLOGY (3-0). An application of psychological principles to problems of personality growth, motivation, and interpersonal relations. PREREQUISITE: PY 2050 or permission of Chairman of the Department.

PY 2352 PSYCHOLOGY IN ACCIDENT PREVENTION AND INVESTIGATION (4-0). A study of logical and psychological principles and practices useful in developing mental efficiency and emotional strength. Designed especially for the Aviation Safety Officer Program.

**SPEECH***Lower Division Courses*

SP 1020 PUBLIC SPEAKING (3-0). Practice in preparing and delivering extemporaneous speeches, emphasizing principles and techniques of oral style.

SP 1021 CONFERENCE PROCEDURES (2-0). Theory and practice of group dynamics applied to conferences, with emphasis on group problem-solving in completed staff work.

SP 1320 BASIC SPEAKING FOR FOREIGN OFFICERS (2-0). Work in preparing and presenting speeches, with attention to the special problems of students with limited experience in speaking English. PREREQUISITE: SP 1320 is prerequisite to SP 1020 for foreign officer-students.

SP 1321 PUBLIC SPEAKING FOR ENGINEERING STUDENTS (2-0). A condensed version of a basic course, oriented toward the interests and needs of the engineer-speaker. Offered only during the first (summer) quarter.

*Upper Division Courses*

SP 2221 ADVANCED SPEECH (2-0). Practical application of techniques learned in SP 1020 with stress on composition, platform technique, audience situations and audience response. Opportunity to address off-campus audiences is provided. PREREQUISITE: SP 1020 or equivalent.

## DEPARTMENT OF MATERIAL SCIENCE AND CHEMISTRY

GILBERT FORD KINNEY, Professor of Chemical Engineering; Chairman (1942)\*; A.B., Arkansas College, 1928; M.S., Univ. of Tennessee, 1930; Ph.D., New York Univ., 1935.

NEWTON WEBER BUEGER, Professor of Metallurgy (1942); B.S., Massachusetts Institute of Technology, 1933; M.S., 1934; Ph.D., 1939.

CARLOS GUILLERMO CARDENAS, Lieutenant, U.S. Naval Reserve, Assistant Professor of Chemistry (1965); B.S., Univ. of Texas, 1962; Ph.D., 1965.

JOHN ROBERT CLARK, Professor of Metallurgy (1947); B.S., Union College, 1935; Sc.D., Massachusetts Institute of Technology, 1942.

JOHN HENRY DUFFIN, Professor of Chemical Engineering (1962); B.S., Lehigh Univ., 1940; Ph.D., Univ. of California at Berkeley, 1959.

WILLIAM WISNER HAWES, Professor of Metallurgy and Chemistry (1952); B.S., Ch.E., Purdue Univ., 1924; Sc.M., Brown Univ., 1927; Ph.D., 1930.

CARL ADOLF HERING, Professor of Chemical Engineering (1946); B.S., Oregon State College, 1941; M.S., Cornell Univ., 1944.

GEORGE DANIEL MARSHALL, JR., Professor of Metallurgy (1946); B.S., Yale Univ., 1930; M.S., 1932.

GEORGE HAROLD MCFARLIN, Professor of Chemistry (1948); B.A., Indiana Univ., 1925; M.A., 1926.

RICHARD ALAN REINHARDT, Professor of Chemistry (1954); B.S., Univ. of California at Berkeley, 1943; Ph.D., 1947.

MELVIN FERGUSON REYNOLDS, Professor of Chemistry (1946); B.S., Franklin and Marshall College, 1932; M.S., New York Univ., 1935; Ph.D., 1937.

CHARLES FREDERICK ROWELL, Assistant Professor of Chemistry (1962); B.S., Syracuse Univ., 1956; M.S., Iowa State Univ., 1959; Ph.D., Oregon State Univ., 1964.

JOHN WILFRED SCHULTZ, Associate Professor of Chemistry (1958); B.S., Oregon State College, 1953; Ph.D., Brown Univ., 1957.

JAMES EDWARD SINCLAIR, Professor of Chemistry (1946); B.S., Ch.Eng., Johns Hopkins Univ., 1945; M.S., Naval Postgraduate School, 1956.

GLENN HOWARD SPENCER, Associate Professor of Chemistry (1962); B.S., Univ. of California at Berkeley, 1953; Ph.D., Univ. of Washington, 1958.

WILLIAM MARSHALL TOLLES, Associate Professor of Chemistry (1962); B.A., Univ. of Connecticut, 1958; Ph.D., Univ. of California at Berkeley, 1962.

JAMES WOODROW WILSON, Professor of Chemical Engineering (1949); B.A., Stephen F. Austin State, 1935; B.S. in Ch.E., Univ. of Texas, 1939; M.S. in Ch.E., Texas A&M College, 1941.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

### DEPARTMENTAL REQUIREMENTS FOR DEGREES IN CHEMISTRY OR MATERIAL SCIENCE

A specific curriculum should be consistent with the general minimum requirements for the degree as determined by the Academic Council.

Any program leading to award of a degree must be approved by the Department of Material Science and Chemistry at least two quarters before completion. In general, approved programs will require more than minimum degree requirements in order to conform to the needs and objectives of the United States Navy.

#### BACHELOR OF SCIENCE IN CHEMISTRY

1. A major in chemistry should include a minimum of 44 quarter hours of chemistry (of which 9 quarter hours are elective), 17 quarter hours of physics (through general and modern physics), 18 quarter hours of mathematics (through differential equations) and 12 quarter hours of elective upper division courses in engineering, mathematics, or science (including chemistry). At least 96 of the quarter hours must be upper division level.

2. The following specific requirements must be met. Courses marked with an asterisk must include laboratory work.

<i>Discipline</i>	<i>Subject</i>	<i>Approximate Quarter Hrs.</i>
Chemistry	General*	4
	Inorganic*	3
	Analytical*	4
	Organic*	9
	Physical*	14
		<hr/> 34
Physics	General*	13
	Modern (Atomic)	4
		<hr/> 17
Mathematics	College Algebra and Trigonometry	4
	Analytical Geometry and Calculus	11
	Differential Equations	3
		<hr/> 18

3. The 9 elective quarter hours in chemistry must be fulfilled by taking at least upper division courses in chemistry or chemical engineering.



**MASTER OF SCIENCE IN CHEMISTRY**

1. To obtain the degree, Master of Science in Chemistry, the student must have completed work equivalent to the Bachelor of Science requirements of this department.

2. In addition the student must successfully complete the following with a grade point average of 2.0 in all chemistry courses:

- a. One course at the 4000 level in each of the following areas: Chemical Thermodynamics, Inorganic Chemistry, Physical-Organic Chemistry and Quantum Chemistry. Minimum total quarter hours—13.
- b. Two or more courses at the 4000 level in the general area chosen for specialization. These courses must have a total of not less than six quarter hours of lecture and must be approved by the Department of Material Science and Chemistry. Minimum total quarter hours—6.
- c. A thesis demonstrating ability to perform independent and original work.
- d. Sufficient supporting courses in science, mathematics and engineering to meet school requirements.

**MASTER OF SCIENCE IN MATERIAL SCIENCE**

1. The following is a statement of departmental minimum requirements for the degree of Master of Science in Material Science. A candidate shall previously have satisfied the requirements for a Bachelor's degree with a major in science or engineering. Credit requirements in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

2. A minimum credit of 16 quarter hours in 4000 level courses in Material Science is required. These shall include at least one course each in the areas of metals, ceramics, and plastics. A minimum of 10 quarter hours of graduate credit must be earned outside the major department. A total of at least 20 quarter hours of 4000 level courses must be included in the program.

3. Completion of a thesis and its acceptance by the department are required. A maximum of 7 quarter hours of graduate credit may be allowed toward satisfaction of the School requirement for 40 quarter hours, but the thesis credit may not be used to satisfy the requirements of paragraph 2.

**CHEMISTRY AND CHEMICAL ENGINEERING***Lower Division Courses*

CH 1001 INTRODUCTORY GENERAL CHEMISTRY (4-2). The first quarter course of a two quarter sequence for students who have not had college chemistry. A study of the principles which govern the physical and chemical behavior of matter. TEXT: Sienko and Plane, *Chemistry*, 3rd ed.

CH 1002 INTRODUCTORY GENERAL CHEMISTRY II (3-2). The second quarter of a two-quarter sequence for

students who have not had chemistry before coming to the Postgraduate School. TEXT: Same as CH 1001. PREREQUISITE: CH 1001.

*Upper Division Courses*

CH 2001 GENERAL PRINCIPLES OF CHEMISTRY (3-2). A study of the fundamental principles of chemistry governing the physical and chemical behavior of matter. Current theories of atomic structure and chemical bonding are particularly emphasized. Also studied are the states of matter and chemical equilibria. Special attention is given to the compounds of carbon. Elementary physical chemistry experiments are performed in the laboratory. TEXT: Mahan, *University Chemistry*. PREREQUISITE: College Chemistry.

CH 2101 INORGANIC ANALYSIS (3-3). Detailed calculation for acid-base and solubility equilibria; the graphical method of Sillen. Oxidation-reduction and the electrode potential. Laboratory work will consist of gravimetric, volumetric and instrumental analyses, especially as used to investigate inorganic reactions. TEXT: Skoog and West, *Fundamentals of Analytical Chemistry*. PREREQUISITE: CH 2402.

CH 2102 INORGANIC CHEMISTRY (2-3). Introduction to reaction mechanisms. Bonding in inorganic compounds. The typical elements. The laboratory will be a continuation of CH 2101, but with emphasis on descriptive inorganic chemistry. TEXT: Cotton and Wilkinson, *Advanced Inorganic Chemistry*, 2nd ed. PREREQUISITE: CH 2101.

CH 2301 ORGANIC CHEMISTRY I (4-2). The first quarter of a two quarter study of the chemistry of organic compounds. TEXT: Roberts and Casserio, *Basic Principles of Organic Chemistry*. PREREQUISITE: CH 2402.

CH 2302 ORGANIC CHEMISTRY II (3-3). A continuation of CH 2301. The study of Organic Chemistry is pursued further with emphasis in the laboratory on synthetic techniques. TEXT: Roberts and Casserio, *Basic Principles of Organic Chemistry*. PREREQUISITE: CH 2301.

CH 2401 GENERAL THERMODYNAMICS (3-0). (See listing of PH 2551.)

CH 2402 INTRODUCTION TO PHYSICAL CHEMISTRY (3-3). The course will include such topics as properties of matter, thermochemistry, chemical thermodynamics, chemical equilibria, kinetics, and electrochemistry. TEXT: Moore, *Physical Chemistry*, 3rd ed. PREREQUISITES: CH 2401, CH 2001.

CH 2405 PHYSICAL CHEMISTRY TOPICS (4-3). Completion of study of topics of undergraduate physical chemistry begun in CH 2402. TEXTS: Moore, *Physical Chemistry*, 3rd ed.; Salzberg et al., *Laboratory Course in Physical Chemistry*. PREREQUISITE: CH 2402.

*Upper Division or Graduate Courses*

CH 3201 CHEMICAL INSTRUMENTS (3-3). A course designed to familiarize the student with modern instrumental techniques of chemical analysis. Emphasis is given to the theoretical basis of the various kinds of measurements made

in the laboratory and the principles involved in the design and construction of analytical instruments. Laboratory experiments will deal with representative analytical problems. TEXTS: Willard, Merritt and Dean, *Instrumental Methods of Analysis*, 4th ed.; Silverstein and Bassler, *Spectrometric Identification of Organic Compounds*. PREREQUISITES: CH 2101, CH 2405.

CH 3401 CHEMICAL THEORY (4-0). An advanced one-term course concerned with topics in chemistry of special interest to physics majors. Topics include chemical bonding and quantum chemistry, molecular spectroscopy, chemical equilibrium, rates of chemical reactions, electrochemical cells, and photo and radiation chemistry. TEXTS: Phillips, *Basic Quantum Chemistry*; Moore, *Physical Chemistry*, 3rd ed. PREREQUISITES: College Chemistry, PH 3651, Matrix Mechanics and CH 2401.

CH 3701 CONTROL SYSTEMS (3-3). (See listing of EE 3411.)

CH 3705 REACTION MOTORS (3-0). A study of the fundamentals of Rocket Motors. The subject matter includes the basic mechanics of Jet Propulsion engines, properties of solid and liquid propellants, the design and performance parameters of rocket motors. TEXTS: Sutton, *Rocket Propulsion Elements*; Warren, *Rocket Propellants*. PREREQUISITE: CH 2401.

CH 3709 EXPLOSIVES CHEMISTRY (3-2). Chemical and physical properties of explosives are related to modes of behavior and physical principles of use. Basic principles of testing and evaluation of explosives. Trends in new developments are surveyed. Independent exploratory work in the laboratory in such areas as manner of initiation, sensitivity, brisance, power, heats of explosion and combustion. TEXTS: Cook, *The Science of High Explosives*; Davis, *Chemistry of Powder and Explosives*; Rinehart and Pearson, *Explosive working of Metals*. PREREQUISITE: CH 2001.

CH 3713 BLAST AND SHOCK EFFECTS (3-0). Generation of blast and shock waves by explosions, propagation of shock waves in air, scaling laws for explosions, shock and blast loads on structures, damage and damage mechanisms, thermal and ionizing radiation effects, principles of protection against damage. TEXT: Kinney, *Shocks in Air*. PREREQUISITES: CH 2401, CH 3401, or CH 2402.

CH 3717 UNIT OPERATIONS (3-2). An introduction to the study of the unit operations of chemical engineering. Selection of and primary emphasis on particular unit operations will be made on the basis of current student specialties. TEXTS: Foust et al., *Principles of Unit Operations*; Bird et al., *Transport Phenomena*; Smith and McCabe, *Unit Operations of Chemical Engineering*. PREREQUISITES: MA 1100, CH 2402, CH 2401.

#### Graduate Courses

CH 4101 ADVANCED INORGANIC CHEMISTRY (3-3). Coordination compounds and crystal field theory. Chemistry of the halogens and of nitrogen. The laboratory introduces the student to general methods for investigating chemical

reactions. TEXT: Cotton and Wilkinson, *Advanced Inorganic Chemistry*, 2nd ed. PREREQUISITES: CH 2102, CH 2405, PH 3651.

CH 4301 PHYSICAL ORGANIC I (3-0). First quarter of a two-quarter sequence. In this term the tools available for the study of organic mechanisms are discussed and appropriate examples used. TEXTS: Hine, *Physical Organic Chemistry*, 2nd ed.; Gould, *Structure and Mechanism in Organic Chemistry*. PREREQUISITES: CH 2302, CH 3201, CH 4401.

CH 4302 PHYSICAL ORGANIC II (3-0). The techniques discussed in CH 4301 are used in the study of organic reaction mechanisms as currently understood. TEXT: See CH 4301. PREREQUISITE: CH 4301.

CH 4401 CHEMICAL THERMODYNAMICS (3-0). Application of thermodynamics to real gases, non-electrolytes, electrolytic solutions, multicomponent solutions. Calculations of equilibria, estimation of thermodynamic quantities and brief discussion of calculations of thermodynamic properties from spectroscopic and other molecular data. TEXTS: Klotz, *Chemical Thermodynamics*; Lewis and Randall, *Thermodynamics*, 2nd ed. PREREQUISITE: CH 2402.

CH 4405 MOLECULAR DYNAMICS (3-0). A study of molecular spectra, utilizing symmetry to obtain information about eigenvalues and selection rules. Spectra discussed will include infrared, Raman, and ultraviolet. Symmetry will be used to give an understanding of electronic structure of molecules and ions. TEXT: Phillips, *Basic Quantum Chemistry*. PREREQUISITES: PH 3651, CH 2405, Matrix Algebra.

CH 4406 QUANTUM CHEMISTRY II (3-0). A study of molecular spectra, emphasizing theory, interpretation, and prediction of spectra by utilizing matrix manipulations. Rigorous solutions to problems will be examined in detail for infrared, Raman, ultraviolet, nuclear magnetic resonance, electron spin resonance, and rotational spectra. PREREQUISITE: CH 4405.

CH 4501 RADIOCHEMISTRY (2-4). Discussion of important aspects of radioactivity from standpoint of the chemical transformations which accompany it and which it may induce; techniques for measurement and study of ionizing radiation; methods of separation of unstable nuclides, identification and assays. TEXT: Johnson, Eichler and O'Kelley, *Nuclear Chemistry*. PREREQUISITE: CH 3401 or equivalent.

CH 4701 PROCESS CONTROL (3-2). A continuation of CH 3701 wherein complex control systems are studied. These include valves and transmission lines, heat exchangers, level control, flow control, control of distillation columns and chemical reactors and finally blending and pH control. Sampled data systems and optimization techniques are considered. TEXTS: Harriott, *Process Control*; Couglanowr and Koppel, *Process Control*. PREREQUISITE: Common Control Course (CH 3701).



CH 4705 PLASTICS AND HIGH POLYMERS (2-2). A study of the general nature of plastics and high polymers, their application and limitations as engineering materials. Also, correlation between properties and chemical structure. In the laboratory plastics are made, molded, tested and identified. TEXTS: Golding, *Polymers and Resins*; Kinney, *Engineering Properties and Application of Plastics*. PREREQUISITE: CH 2001.

CH 4709 APPLIED MATHEMATICS OF CHEMICAL ENGINEERING (3-2). The differential equations describing various chemical engineering processes are derived and solved using analytic and numeric techniques. Electronic computers will be used to obtain solutions to problems. TEXTS: Mickley et al., *Applied Mathematics in Chemical Engineering*; Wylie, *Advanced Engineering Mathematics*. PREREQUISITES: MA 1100, CH 2401, CH 2402.

CH 4800 SPECIAL TOPICS (2-0 to 4-0). Pursuit of deeper understanding of some topic chosen by the student and the instructor; may involve directed reading and conference or a lecture pattern. May be repeated for credit with a different topic. Typical topics are listed as follows:

- 1) Kinetics—Chemical engineering applications with emphasis on large scale equipment design.
- 2) Heat Transfer—Chemical engineering applications with emphasis on large scale and unusual equipment design.
- 3) Radiochemistry—Theory of chemical nuclear processes and detection methods of their radiations.
- 4) Statistical Mechanics—Statistical thermodynamics and other applications to chemical systems.
- 5) Chemical Kinetics—Interpretation of data, theories, mechanism.
- 6) Natural Products—Study of degradation and synthesis of steroids, alkaloids and terpenes.
- 7) Advanced Organic Chemistry—Study of new synthetic approaches in depth.
- 8) The Chemistry of High Polymers— Discussion of chemistry of polymer formation and properties.

TEXT: As appropriate. PREREQUISITE: Consent of the instructor.

## MATERIALS

### Lower Division Courses

MS 1021 ELEMENTS OF MATERIALS SCIENCE I (3-2). An introduction to the nature and properties of materials for engineering applications. An essentially qualitative treatment of factors which govern the selection of materials. Classification of materials by type based on their chemical, physical and mechanical properties. Methods, processes and problems in the production of commercial materials. Introduction to crystal structure, phase equilibria, plastic deformation, recrystallization, grain growth, and precipitation hardening. TEXT: Keyser, *Basic Engineering Metallurgy*. PREREQUISITE: CH 1001 or equivalent.

MS 1022 ELEMENTS OF MATERIALS SCIENCE II (2-2). Continuation of subject matter introduced in MS

1021 with stress on specific materials systems such as steel, plastics, and composites. Discussion of environmental factors and suggestions for avoiding or interpreting service failures. TEXT: Keyser, *Basic Engineering Metallurgy*. PREREQUISITE: MS 1021.

### Upper Division Courses

MS 2201 ENGINEERING MATERIALS I (3-2). Principles underlying those properties and characteristics of materials which govern their selection and behavior in engineering applications. The importance of crystallographic concepts, imperfections, and dislocations in determining properties is emphasized. Elastic and plastic behavior of crystalline and non-crystalline solids are studied and compared. Specific topics include atomic bonding, crystal structure, grain structure, defects and imperfections, slip, twinning, fracture, phase equilibria, mechanisms of phase changes, recrystallization, grain growth, and precipitation hardening. Materials systems with extensive naval application are used to illustrate the theoretical background. TEXT: Clark and Varney, *Physical Metallurgy for Engineers*. PREREQUISITES: CH 2001 or General Physics.

MS 2202 ENGINEERING MATERIALS II (3-2). Extension of subject matter introduced in MS 2201. Control of reaction rates in solid phase transformation; diffusion and diffusionless transformations; engineering alloy systems including iron, steel, alloy steels, stainless steels, PH stainless steels, high temperature alloys, modern ultra high strength steels; principles of ausforming, marstraining, maraging; cryogenic materials, refractory materials, powder metallurgy, cermets, composite materials; as time permits, mechanical properties such as fatigue, creep, and fracture are discussed, as well as welding problems. TEXT: Clark and Varney, *Physical Metallurgy for Engineers*. PREREQUISITE: MS 2201.

MS 2218 ELEMENTS OF ENGINEERING MATERIALS (3-2). A broad survey of the field of engineering materials with special emphasis on those of importance to the aeronautical engineer. A review of fundamental principles such as crystallography, imperfections, dislocations, polymorphism, solid solution, equilibrium diagrams, non-equilibrium phenomenon, recrystallization, grain growth, and precipitation hardening. Effect of various mechanical and thermal treatments on the structure and properties of cryogenic and aerospace materials, including steels, stainless steels, precipitation hardening alloys, the light alloys, cermets, composites, and a correlation of the foregoing principles with corrosion, creep, and fatigue type failures. TEXTS: Guy, *Physical Metallurgy for Engineers*; Clark and Varney, *Physical Metallurgy for Engineers*; Parker, *Materials for Missiles and Spacecraft*. PREREQUISITES: Recent elementary courses in physics and chemistry.

MS 2228 INTRODUCTION TO ENGINEERING MATERIALS (3-2). A survey emphasizing the relations between composition, thermal and mechanical treatments and the engineering properties of materials of interest to the naval engineer. Topics covered include crystal fracture concepts, phases present under equilibrium and non-equilibrium con-



ditions, kinetics of phase transformation, plastic deformation and recrystallization. The variation of mechanical properties by dislocations is examined. Magnetic materials and other topics of particular interest to electrical engineers will be discussed in the time available. TEXTS: Guy, *Physical Metallurgy for Engineers*; Clark and Varney, *Physical Metallurgy for Engineers*. PREREQUISITES: Recent elementary courses in physics, chemistry and mechanics.

#### *Upper Division or Graduate Courses*

MS 3303 NUCLEAR REACTOR MATERIALS (3-0). A discussion of materials used in reactor construction including fuels, moderators, absorbers, shielding materials, structural materials and coolants. While the nuclear requirements dictating the use of specific materials are pointed out and radiation effects are discussed, emphasis is on the technology of the materials. TEXTS: Reactor Handbook, 2nd ed.; Kaufmann, *Nuclear Reactor Fuel Elements*. PREREQUISITE: MS 2202.

MS 3304 CORROSION (3-2). A course designed to give a knowledge of the chemical and electrochemical mechanism of corrosion and the environmental and stress factors that affect the rate of corrosion. Methods of control such as cathodic protection, alloying, protective coatings, and inhibitors will be considered. TEXT: Uhlig, *Corrosion and Corrosion Control*. PREREQUISITE: MS 2202.

MS 3601 PHYSICAL GEOLOGY (3-2). The study of the various geological phenomena. Topics discussed are: brief fundamentals of crystallography; mineralogy; the rock forming minerals; classification of rocks; igneous, sedimentary, and metamorphic rocks; weathering and erosion; steam sculpture; glaciation; surface and sub-surface waters; volcanism, isostasy, and dynamic processes; continents; submarine geology and topography; interpretation of topographic and geologic maps; plane table surveying. TEXTS: Hurlbut, *Dana's Manual of Mineralogy*; Gulluly, *Principles of Geology*. PREREQUISITES: CH 1001 or CH 2001.

MS 3701 CRYSTALLOGRAPHY AND X-RAY DIFFRACTION TECHNIQUES (2-3). The essential concepts of crystallography including atomic bonding, symmetry, point groups, lattices, space groups, coordinate systems, crystal classes, crystal systems; the orthogonal, spherical, gnomonic, and stereographic projections; the optical goniometer; fundamentals of optical crystallography, and the use of the polarizing microscope; twinning isomorphism, polymorphism; the structure of the silicates; the theory of X-ray diffraction, and the various diffraction techniques used in the study of crystalline materials. TEXTS: Wood, *Crystals and Light*; Azaroff and Buerger, *The Powder Method*. PREREQUISITE: Recent course in general physics.

#### *Graduate Courses*

MS 4205 THE STRUCTURE OF SOLIDS (3-4). The principle topic considered in this course is the identification and description of the phases present in alloys or other

aggregates. The course is not only concerned with the methods by which structures are determined but also considers the correspondence between mechanical, electrical and magnetic properties and structure. X-ray diffraction methods of studying single crystals and polycrystalline aggregates are described and correlated with optical crystallography and microscope examination. Extensive individual initiative is allowed and expected in the laboratory. TEXTS: Rhines, *Phase Diagrams in Metallurgy*; Cullity, *Elements of X-ray Diffraction*; Guinier, *X-ray Diffraction*. PREREQUISITES: MS 2202 or PH 3651.

MS 4206 THE STRUCTURE AND MECHANICAL PROPERTIES OF CRYSTALS (3-2). A discussion of dislocations in crystals and the mechanical properties to be expected in real crystals. The topics discussed include the forces between dislocations, stacking faults and partial dislocations, the generation of dislocations during crystal growth and during plastic deformation, the locking of dislocations. The experimental investigation of dislocations by optical methods, decorating techniques, electron transmission microscopy, and diffraction methods are discussed. TEXTS: Fridel, *Dislocations*; Weertman and Weertman, *Elementary Dislocation Theory*; Amelinck, *The Direct Observation of Dislocations*. PREREQUISITES: MS 2202, PH 3651.

MS 4215 PHASE TRANSFORMATIONS (3-4). The thermodynamics and kinetics of transformations in solids. The free energy of alloys, solidification, precipitation, recrystallization, diffusion and diffusionless transformations. Extensive individual initiative is allowed and expected in the laboratory. TEXTS: Reed-Hill, *Physical Metallurgy Principles*; Fine, *Introduction to Phase Transformations in Condensed Systems*; Wayman, *Introduction to the Crystallography of Martensite Transformation*. PREREQUISITE: MS 2202.

MS 4300 MATERIALS SCIENCE COLLOQUIUM (1-0). Topics of current interest are presented by invited speakers, faculty members and students. PREREQUISITE: Consent of the instructor.

MS 4302 SPECIAL TOPICS IN MATERIAL SCIENCE (hours by arrangement). Independent study of advanced subjects not regularly offered. PREREQUISITE: Consent of the instructor.

MS 4305 MATERIALS FOR ELECTRICAL AND ELECTRONIC APPLICATIONS (3-0). The properties and preparation of materials used in electrical and electronic applications. Among the materials discussed are ferromagnetic materials, both hard and soft, ferrimagnetic materials, semiconductors, both elemental and compound, insulators and dielectrics, piezoelectric and ferroelectric crystals. The electronic, crystallographic and thermodynamic principles controlling these materials are discussed and the heat treatments, compositions and methods of fabrication of commercial materials are emphasized. TEXT: Nusbaum, *Electronic and Magnetic Behavior of Materials*. PREREQUISITE: MS 2202.

MS 4312 MATERIALS SYSTEMS (3-0). Attempts to establish criteria of standard environment and standard behavior of engineering materials. Examines properties of materials at extremes of temperature, rate and duration and frequency of loading, corrosive environment, and the conditions of outer space. Examines factors amenable to control at the molecular and structural levels and illustrates with real materials. Development of materials to meet requirements of extreme environmental conditions is illustrated by alloy steels, refractory metals and alloys, composites, cermets and special materials. TEXT: Dorn, *Mechanical Behavior of Materials at Elevated Temperatures*. PREREQUISITE: MS 2202.

MS 4320 PROPERTIES OF CERAMIC MATERIALS (4-0). Occurrences, syntheses and properties of ceramic raw materials. Kinetic and phase equilibrium principles underlying the production of ceramics and glasses. Structure of typical ceramics and glasses. TEXT: Kingery, *Introduction to Ceramics*. PREREQUISITE: CH 2402.

MS 4401 PHYSICS OF SOLIDS (3-0). A course intended for students particularly interested in materials science and which will cover topics being developed in the literature but with emphasis on crystallographic and mechanical subjects such as order-disorder, symmetry and anti-symmetry, twinning, brittle fracture, transition temperatures, etc. TEXTS: Instructors Notes, Current Literature. PREREQUISITES: MS 4205 or MS 4215 or PH 3780 or PH 4751.

MS 4811 MECHANICAL BEHAVIOR OF ENGINEERING MATERIALS (3-0). The response of single crystals and polycrystalline aggregates to mechanical stress. The plastic deformation and fracture of real materials including metals and alloys, ceramics and cermets, composites, and polymers. Fracture resulting from fatigue and environmental conditions will be discussed. Creep and mechanical properties at elevated temperature will be described and current theories discussed. TEXT: Dieter, *Mechanical Metallurgy*. PREREQUISITES: MS 2202, Engineering Mechanics.

## DEPARTMENT OF MATHEMATICS

ROBERT EUGENE GASKELL, Professor of Mathematics; Chairman (1966)\*; A. B., Albion College, 1933; M.S., Univ. of Michigan, 1934; Ph.D., 1940.

ALADUKE BOYD MEWBORN, Distinguished Professor and Professor Emeritus of Mathematics and Mechanics (1946); B.S., Univ. of Arizona, 1927; M.S., 1931; Ph.D., California Institute of Technology, 1940.

CHARLES HENRY RAWLINS, JR., Professor Emeritus of Mathematics and Mechanics (1922); Ph.B., Dickinson College, 1910; M.A., 1913; Ph.D., Johns Hopkins Univ., 1916.

RICHARD DONALD AMORI, Lieutenant (junior grade), U.S. Navy; Instructor in Mathematics (1965); B.S., Univ. of Scranton, 1964; M.S., Bucknell Univ., 1965.

HORACE CROOKHAM AYRES, Professor of Mathematics (1958); B.S., Univ. of Washington, 1931; M.S., 1931; Ph.D., Univ. of California at Berkeley, 1936.

WILLARD EVAN BLEICK, Professor of Mathematics (1946); M.E., Stevens Institute of Technology, 1929; Ph.D., Johns Hopkins Univ., 1933.

RICHARD CROWLEY CAMPBELL, Professor of Mathematics (1948); B.S., Muhlenberg College, 1940; M.A., Univ. of Pennsylvania, 1942.

WARREN RANDOLPH CHURCH, Professor of Mathematics (1938); B.A., Amherst, 1926; M.A., Univ. of Pennsylvania, 1930; Ph.D., Yale Univ., 1935.

FRANKLIN LEE DANIELS, Lieutenant (junior grade), U.S. Naval Reserve; Instructor of Mathematics (1966); B.A., Oklahoma City Univ., 1964; M.A., Univ. of Oklahoma, 1966.

FRANK DAVID FAULKNER, Professor of Mathematics (1950); B.S., Kansas State Teachers College, 1940; M.S., Kansas State College, 1942.

JOSEPH GIARRATANA, Professor of Mathematics (1946); B.S., Univ. of Montana, 1928; Ph.D., New York Univ., 1936.

HERBERT J. HAUER, Assistant Professor of Mathematics (1963); B.S., Queens College, 1949; M.A., Univ. of California at Berkeley, 1955.

WALTER JENNINGS, Professor of Mathematics (1947); B.A., Ohio State Univ., 1932; B.S., 1932; M.A., 1934.

UNO ROBERT KODRES, Associate Professor of Mathematics (1963); B.A., Wartburg College, 1954; M.S., Iowa State Univ., 1956; Ph.D., 1958.

ERIC SIDDON LANGFORD, Assistant Professor of Mathematics (1964); B.S., Massachusetts Institute of Technology, 1959; M.S., Rutgers Univ., 1960; Ph.D., 1963.

KENNETH ROBERT LUCAS, Associate Professor of Mathematics (1958); B.S., Washburn Univ., 1949; Ph.D., Kansas Univ., 1957.

HERMAN BERNHARD MARKS, Associate Professor of Mathematics (1961); B.S., Southern Methodist Univ., 1950; M.A., Univ. of Texas, 1959.

HUGO MURUA MARTINEZ, Professor of Mathematics (1964); B.A., Univ. of California, 1952; M.S., Stanford Univ., 1961; Ph.D., Univ. of Chicago, 1963.

JOHN PHILIP PIERCE, Professor of Mathematics (1948); B.S. in E.E., Worcester Polytechnic Institute, 1931; Master of E.E., Polytechnic Institute of Brooklyn, 1937.

FRANCIS MCCONNELL PULLIAM, Professor of Mathematics (1949); B.A., Univ. of Illinois, 1937; M.A., 1938; Ph.D., 1947.

ELMO JOSEPH STEWART, Professor of Mathematics (1955); B.S., Univ. of Utah, 1937; M.S., 1939; Ph.D., Rice Institute, 1953.

CHARLES CHAPMAN TORRANCE, Professor of Mathematics (1946); M.E., Cornell Univ., 1922; M.A., 1927; Ph.D., 1931.

DONALD HERBERT TRAHAN, Associate Professor of Mathematics (1966); B.S., Univ. of Vermont, 1952; M.A., Univ. of Nebraska, 1954; Ph.D., Univ. of Pittsburgh, 1961.

FRANCIS MERRILL WILLIAMS, Assistant Professor of Mathematics (1965); B.S., New Mexico State Univ., 1958; M.S., 1960; Ph.D., 1964.

RICHARD PAUL WOODRING, Lieutenant, U.S. Naval Reserve; Instructor in Mathematics (1964); B.A., Washington and Jefferson College, 1957; M.S., Univ. of Utah, 1959.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

## DEGREES WITH MAJOR IN MATHEMATICS

Officer students may, under certain conditions, be offered the opportunity to qualify for either a Bachelor of Science or Master of Science degree with major in mathematics. Any interested student should consult the Chairman of the Department of Mathematics for an evaluation of his previous work to determine his potential for obtaining either degree and to consider the possibility of scheduling the necessary work. Evaluation of courses presented upon entering the Postgraduate School for credit toward these degrees must be completed prior to entering a program leading to these degrees. The requirements in mathematics for these degrees are given below.

Each student majoring in mathematics will set up in advance, in consultation with the Chairman of the Department, and approved by him, a mathematics curriculum fitted to his aims, aptitudes, preparation, and interests. This original curriculum may, however, be modified as work progresses, but only with the approval of the Chairman of the Department.



### BACHELOR OF SCIENCE WITH MAJOR IN MATHEMATICS

1. Of the total quarter hours specified in the general requirements for the degree of Bachelor of Science, a student majoring in mathematics must complete at least 30 quarter hours of approved course work in mathematics beyond the calculus, and must have an average QPR of 1.25 or higher in these 30 quarter hours.

2. These 30 quarter hours in mathematics will include course work in differential equations and complex variables, and in addition at least six quarter hours in each of the two fields, analysis and algebra.

### MASTER OF SCIENCE WITH MAJOR IN MATHEMATICS

1. A student pursuing a program leading to a Master of Science degree with major in mathematics must have completed work which would qualify him for a Bachelor of Science degree with major in mathematics. A student whose background does not satisfy this requirement may take course work to eliminate this deficiency while simultaneously pursuing the Master of Science Program. However, course work pursued to eliminate this deficiency cannot be counted toward satisfying either the general or departmental requirements for the degree of Master of Science.

2. A curriculum satisfying the requirements for the Master of Science degree with major in mathematics consists of at least 45 quarter hours of approved course work in mathematics, or approved course work in mathematics and related subjects. Of these 45 hours, there will be at least six hours in each of the fields of analysis and algebra. A student must have an average QPR of 2.125 or better in the course work composing this curriculum.

3. At the discretion of the Chairman of the Department of Mathematics a student pursuing a program leading to the Master of Science degree with major in mathematics may (or may not) be required to write a thesis in mathematics. If a student writes an acceptable thesis, then he will be given the equivalent of nine quarter hours of course work for the thesis.

4. In addition to the above requirements, a student must pass a comprehensive examination in mathematics. This examination is given twice each year, and normally the student will take his examination within the academic year of the award of the Master of Science degree.

### COMPUTER SCIENCE

#### *Upper Division Courses*

CS 2100 INTRODUCTION TO COMPUTERS AND PROGRAMMING (4-0). Characteristics of general purpose digital computers. Fundamentals of programming, Programming aids. Use of assembly routines and compilers. Procedure-oriented languages, e.g., FORTRAN. Problems selected from numerical and non-numerical areas. Military applications of computers. PREREQUISITE: None.

CS 2110 INTRODUCTION TO COMPUTER PROCESSES (3-0). Concept and properties of an algorithm; language and notation of describing algorithms. Problem analysis and solution. Application of a specific procedure-oriented language, such as FORTRAN, to solve simple numerical and non-numerical problems using a computer. PREREQUISITE: None.

#### *Upper Division or Graduate Courses*

CS 3111 COMPUTER ORGANIZATION AND PROGRAMMING (4-0). Logical organization of a computer. Machine representations of information, machine language and instruction repertoires. Input-output considerations. Subroutines, macros, interpretive and assembly systems. Monitor systems. PREREQUISITE: CS 2110 or equivalent.

\*CS 3200 LOGICAL DESIGN OF DIGITAL COMPUTERS (4-0).

CS 3201 COMPUTER SYSTEMS DESIGN I (4-0). Some considerations in the design of a computer system. Storage, accessing, data paths, control, logical and arithmetical units. Sequential control, concurrent operations. Input-output devices. PREREQUISITES: CS 3200 and CS 3111.

CS 3204 DATA COMMUNICATIONS (4-0). Quantitative study of communication processes. Concepts fundamental to the engineering of accurate, efficient communication links and systems. Elements of information theory. Communication channels and their capacity; encoding and decoding of data over noisy channels. Error detection and correction. Coding schemes; binary systems. Design of effective transmission links in computer-based systems. Survey of devices available for data communications in a military environment. Real-time control systems. PREREQUISITES: CS 3111, CS 3200, MA 2232.

\*CS 3300 INFORMATION STRUCTURES (3-0).

\*CS 3500 MILITARY APPLICATION OF COMPUTERS (4-0).

#### *Graduate Courses*

CS 4112 SYSTEMS PROGRAMMING I (4-0). Design of programs which process programs. Natural and artificial language. Theory and construction of assembly, interpretive and compiler programs. Executive routines, input-output control systems and operating systems. PREREQUISITE: CS 3111.

CS 4113 SYSTEMS PROGRAMMING II (4-0). Continuation of CS 4112. Further study of operating systems for both batch-processing and interactive computing. Special software considerations for multi-programming and multi-processing operations. Design of conversational languages and compilers. PREREQUISITE: CS 4112.

CS 4200 COMPUTER SYSTEMS DESIGN II (4-0). Hardware-software design for different types of computer systems. Concepts such as multi-programming, multi-proc-

essing, time-sharing, priority systems, real-time control hybrid computation. Data acquisition devices and the computers. Study of military command and control systems. Requirements for tactical and strategic processing. PREREQUISITE: CS 3201.

CS 4310 NON-NUMERICAL INFORMATION PROCESSING (4-0). Heuristic and algorithmic methods. Artificial intelligence and simulation of cognitive behavior. Pattern recognition. Simulation of learning and concept formation, decision-making, man-machine relationships. Self-organizing systems. PREREQUISITE: CS 3111.

CS 4900 ADVANCED TOPICS IN COMPUTER SCIENCE (3-0). Analysis and discussion of selected aspects of the field of current research interest, e.g., multi-processing computer systems, formal languages, artificial intelligence, automata theory. PREREQUISITE: Consent of Instructor.

\* See listing under Electrical Engineering Department.

## MATHEMATICS

### *Lower Division Courses*

MA 1000 BASIC ALGEBRA AND TRIGONOMETRY (4-0). Arithmetic processes. The real number system. Engineering notation and the slide rule. Algebraic operations. Linear equations. Graphs. Laws of exponents. Quadratic equations; the quadratic formula. Definition of trigonometric functions. Solution of the right triangle. PREREQUISITE: None.

MA 1010 INTERMEDIATE ALGEBRA (4-0). The set of real numbers and postulates for the development of the algebra of real numbers. Proofs of some elementary theorems for the algebra of the real numbers. Applications of the postulates and theorems to addition, subtraction, multiplication, division and factoring of algebraic expressions. Application to word problems, first degree equations and equations of higher degree. Functions, graphs and inequalities. Exponents and logarithms. Sequences, series and the binomial theorem. Complex numbers. PREREQUISITE: None.

MA 1021 COLLEGE ALGEBRA AND TRIGONOMETRY (4-0). Brief review of algebraic fundamentals. Slide rule and logarithmic methods of computation. Algebra of complex numbers, quadratic equations. Systems of equations, determinants, Cramer's rule. Binomial theorem. Mathematical induction. Trigonometric functions of the general angle. Identities. Solution of right and oblique triangles. Elements of the theory of equations. PREREQUISITE: MA 1010 or equivalent.

MA 1030 ELEMENTARY SETS WITH APPLICATIONS (3-0). Study of the vital role played by set theory throughout contemporary mathematics. A brief introduction to naive set theory is followed by an elementary treatment of logic and the nature of mathematical proof. Techniques of informal proof are implemented in proving standard theorems about sets. Following a study of relation and function as an application of set theory, a Boolean algebra is defined

and used to summarize the algebra of both sets and logic. A final application is given through a systematic treatment of finite probability theory from a set theory point of view. PREREQUISITE: None.

MA 1100 CALCULUS REVIEW (4-0). Functions of one variable, limits, derivatives, continuity, indefinite and definite integrals, transcendental functions, Taylor's theorem, vectors in two and three dimensions, functions of several variables, partial derivatives, multiple integration. PREREQUISITE: A previous course in calculus.

MA 1101 REVIEW OF CALCULUS FUNDAMENTALS (5-0). Development of the real numbers as an ordered field. Study of limits. Review of elementary calculus, including basic differentiation and integration formulas, Taylor's theorem. Calculus of functions of several variables, partial derivatives, chain rule differentiation, Jacobians, multiple integrals and transformation of integrals. PREREQUISITE: A previous course in calculus.

MA 1105 CALCULUS AND ANALYTIC GEOMETRY I (5-0). Introduction to plane analytic geometry, functions of one variable, limits, derivative of rational functions, indefinite integrals, definite integration with applications, elementary transcendental functions. PREREQUISITE: MA 1021.

MA 1106 CALCULUS AND ANALYTIC GEOMETRY II (5-0). Methods of integration, improper integrals, conic sections, hyperbolic functions, polar coordinates, introduction to vector algebra in two and three dimensional space, functions of several variables, tangent plane and normal line, partial differentiation. PREREQUISITE: MA 1105.

MA 1107 CALCULUS AND ANALYTIC GEOMETRY III (3-0). Higher order partial derivatives, maxima and minima for functions of two variables, multiple integrals with applications, infinite series, L'Hospital's rule, introduction to differential equations. PREREQUISITE: MA 1106.

MA 1110 REVIEW OF ELEMENTARY CALCULUS (5-0). A review of selected topics in the calculus of one variable including an introduction to differential equations. PREREQUISITE: A previous course in calculus.

MA 1115 CALCULUS I (5-0). Introduction to plane analytic geometry, functions of one variable, limits continuity, derivatives, indefinite and definite integrals, transcendental functions, conic sections, elementary vector algebra, vector differentiations. PREREQUISITE: Some previous work in calculus.

MA 1116 CALCULUS II (5-0). Polar coordinates, vector algebra and vector calculus in three dimensional space, functions of several variables, double and triple integrals, infinite series, introduction to differential equations. PREREQUISITE: MA 1115.

### *Upper Division Courses*

MA 2025 LOGIC, SETS AND FINITE MATHEMATICS (3-0). Elements of set theory, axiomatics and propositional logic. Elementary number theory. Introduction to the algebra of matrices. PREREQUISITE: None.



MA 2042 LINEAR ALGEBRA (4-0). Elementary matrix algebra. Vector spaces, linear dependence, basis, dimension, rank. Systems of linear equations. Determinants. Linear transformations, change of basis, characteristic, equation, roots and vectors of a matrix. Special matrices: symmetric, orthogonal, inverse. Orthogonal reduction of symmetric matrix. Inverse by partitioning. Introduction to quadratic forms. Cayley Hamilton theorem. Algebra of vectors through triple products. Calculus of vectors including introduction to gradient, divergence, curl. PREREQUISITE: MA 1101 (may be taken concurrently).

MA 2045 INTRODUCTION TO LINEAR ALGEBRA (3-0). Complex numbers. Systems of linear algebraic equations. Matrix algebra. Vector spaces. Rank. Inverse by Gauss' method. Determinants. Adjoint and inverse. Characteristic equation, roots and vectors—proper axes for quadric surface, solution of system of differential equations. Orthogonal reduction to diagonal form. PREREQUISITE: MA 1100 or equivalent.

MA 2110 SELECTED TOPICS FROM ADVANCED CALCULUS (4-0). A selection of topics from Advanced Calculus, such as first order differential equations, linear differential equations with constant coefficients, systems of linear equations, Laplace transforms, introduction to functions of a complex variable, Fourier series, improper integrals, Beta and Gamma functions, operations with integrals. PREREQUISITE: MA 1101 or equivalent.

MA 2121 DIFFERENTIAL EQUATIONS AND INFINITE SERIES (4-0). Ordinary differential equations; infinite series of constants and functions; Taylor series in one and two variables with remainder; series solutions of ordinary differential equations including Bessel's equation; Fourier series. PREREQUISITE: MA 1100 or equivalent.

MA 2130 REVIEW OF SELECTED TOPICS OF ENGINEERING MATHEMATICS (4-0). Taylor and Fourier expansions. Linear differential equations, including series solutions. Bessel functions and Legendre polynomials; applications in the solution of partial differential equations. Sturm Liouville systems and orthogonal-function expansions in solving boundary-value problems. PREREQUISITE: Consent of Instructor.

MA 2161 INTRODUCTION TO MATHEMATICAL PHYSICS (3-0). An introduction to the techniques used in solving problems in the classical field theories. Vector and scalar fields are studied. Solutions to the source-free equations most often encountered in physics are discussed. PREREQUISITES: MA 1100 and MA 2121 (the latter may be taken concurrently).

MA 2172 INTRODUCTION TO COMPLEX VARIABLES (3-0). Complex numbers and their algebra. Regions of the complex plane. Analytic functions, elementary functions, integration and series representations. Residue theory. PREREQUISITE: MA 2121 or equivalent.

MA 2181 INTRODUCTION TO VECTORS (3-0). A course in vector algebra and analysis designed for students unable to satisfy the MA 1100 prerequisite for MA 3181. Vector differential and integral calculus in rectangular and

orthogonal curvilinear coordinate systems; applications in various fields of engineering. PREREQUISITES: MA 1115 and MA 1116 (the latter may be taken concurrently).

MA 2232 NUMERICAL METHODS AND FORTRAN PROGRAMMING (4-0). Structure of computers and basic FORTRAN. Error propagation. Evaluation of functions by power series and Chebyshev series. Telescoping of series. Rational approximations. DO loops and arrays. Roots of nonlinear equations. Subroutines, evaluation of integrals by trapezoidal, Simpson's and Gauss' quadrature formulae. Elimination and iteration techniques to solve linear systems of equations. Curve and surface fitting. Runge-Kutta and predictor-corrector methods for differential equations. The students are expected to complete eight to ten FORTRAN programs of increasing complexity. PREREQUISITE: MA 2121 or equivalent.

MA 2300 MATHEMATICS FOR MANAGEMENT (5-0). This course is designed to provide the mathematical basis for modern managerial tools and techniques. It includes a review of algebra, systems of linear equations and linear inequalities, introductory material from linear programming, vectors and matrices, a brief survey of differential and integral calculus, and fundamentals of probability. PREREQUISITE: None.

MA 2550 ELEMENTARY NUMBER THEORY (3-0). Divisibility, congruences, quadratic reciprocity, Diophantine equations, continued fractions, partitions. PREREQUISITE: Consent of Instructor.

MA 2580 PROJECTIVE GEOMETRY (3-0). A brief intuitive introduction to projective geometry, Desargues' theorem, projectivities, cross-ratios after which the subject is begun on an axiomatic basis. Coordinates are introduced in the projective plane on the basis of Desargues' theorem in the noncommutative case, and Pappus' theorem (in the commutative case). Higher dimensional spaces, conics and linear transformations. PREREQUISITE: Consent of Instructor.

#### *Upper Division or Graduate Courses*

MA 3042 LINEAR ALGEBRA (5-0). Systems of linear algebraic equations. Matrix algebra. Vector spaces. Rank. Inverse by Gauss' method. Determinants. Adjoint and inverse. Characteristic equation, roots, vectors—proper axes for a quadric surface, applications to systems of differential equations. Similarity to a diagonal matrix. Special types of matrices. Orthogonal reduction to diagonal form. Quadratic forms and reductions. Lambda matrices and related topics. Cayley-Hamilton theorem and reduced characteristic function. Canonical forms of a matrix and applications—systems of differential equations, stability criteria, matrix equations. PREREQUISITE: MA 2121 or equivalent.

MA 3046 LINEAR ALGEBRA (3-0). Special types of matrices. Orthogonal reduction of a real symmetric matrix to diagonal form. Quadratic forms and reductions to expressions involving only squares of the variables. Applications to maxima and minima. Lambda matrices and related topics. Cayley-Hamilton theorem. PREREQUISITE: MA 2045.



MA 3047 LINEAR ALGEBRA (3-0). Reduced characteristic function. Canonical forms. Idempotent and nilpotent matrices. Solutions of matrix polynomial equations. Functions of a square matrix. Applications such as to differential equations, stability criteria. PREREQUISITE: MA 3046.

MA 3053 GRAPH THEORY AND COMBINATORIAL ANALYSIS (3-0). Permutations and combinations. Generating functions. The principle of inclusion and exclusion. Partitions, compositions. Trees and networks. Paths, circuits, chains and cycles of a graph. The fundamental numbers in graph theory. Associated matrix and incidence matrix. Transportation networks. PREREQUISITE: MA 1030 or equivalent.

MA 3063 ALGEBRAIC FOUNDATIONS OF COMPUTER SCIENCE (3-0). Discussion of algebraic structures, e.g., groups, rings, integral domains and fields. Finite fields. Ordering relations, lattices and Boolean algebras; mathematical logic, recursive function theory. PREREQUISITE: MA 1030.

MA 3132 PARTIAL DIFFERENTIAL EQUATIONS AND INTEGRAL TRANSFORMS (4-0). Solution of boundary value problems by separation of variables; Sturm-Liouville problems; Fourier, Bessel and Legendre series solutions; Laplace and Fourier transforms; classification of second order equations; applications. PREREQUISITE: MA 2121 or equivalent.

MA 3172 COMPLEX VARIABLES (4-0). Analytic functions, integration and series representations. Residue theory and application to Laplace transform. Conformal mapping and applications. PREREQUISITE: MA 2121 or equivalent.

MA 3173 LAPLACE TRANSFORM (3-0). Definition and some elementary properties of the Laplace transform. Application of these properties to the solution of a differential and/or difference equation. Laplace integral as a complex integral. The inversion integral. The inverse transform by residues. Further properties and applications of the transform to include application to boundary value problems. PREREQUISITE: MA 3172.

MA 3181 VECTOR ANALYSIS (3-0). Vector differential and integral calculus in rectangular and orthogonal curvilinear coordinate systems; applications in various fields of engineering. PREREQUISITE: MA 1100 or equivalent.

MA 3185 TENSOR ANALYSIS I (3-0). Definition of a tensor. Algebra of tensors. The metric tensor. The geometric representation of vectors in general coordinates. The covariant derivative and its application to geodesics. The Riemann tensor, parallelism, and curvature of space. PREREQUISITE: Consent of Instructor.

MA 3212 SELECTED TOPICS IN APPLIED ANALYSIS (4-0). First and higher order iterative processes. Approximations of functions and/or data by polynomials and rational functions. Least squares. Orthogonal functions to include Legendre, Laguerre, Hermite and Chebyshev polynomials. Continued fractions, representation of elementary

functions as continued fractions. Rational approximations of functions by continued fractions and relation to Padé approximation. Linear difference equations, their solutions and relation to the theory of ordinary differential equations. Solutions of difference equations as approximations to continued fractions. PREREQUISITE: MA 2172 or equivalent.

MA 3232 NUMERICAL ANALYSIS (4-0). Solution of equations. Iterative methods for solving systems of equations. Zeros of polynomials. Interpolation and approximation. Numerical differentiation and quadrature. Matrix manipulations; linear simultaneous algebraic equations. Numerical solutions of ordinary differential equations. PREREQUISITE: MA 2121 and FORTRAN programming or equivalent.

MA 3243 NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS (4-1). Finite difference approximations for derivatives. Truncation and discretization errors. Parabolic and hyperbolic equations. Explicit and implicit methods. The Crank-Nicolson method. The implicit alternating direction method. Approximations at irregular boundaries. Elliptic equations. The Liebmann method. Systems of partial differential equations. Students are expected to write FORTRAN programs for the above methods. A term project involving the solution of a suitably difficult boundary value problem is required. PREREQUISITES: MA 2232 and MA 3132 or equivalent.

MA 3352 MISSILE MECHANICS (3-0). A survey of ballistic missile dynamics including discussions of atmospheric structure; standard conditions; drag; stability derivatives; equations of yawing, swerving and angular motion; electronic digital integration of equations of motion; effects of variations from standard conditions; rocket motor thrust and torque; tricyclic motion; aeroballistic range measurements of stability derivatives; contributions of aerodynamic jump and drift to dispersion; dynamic wind tunnel tests; dynamic stability. PREREQUISITE: A course in dynamics.

MA 3362 ORBITAL MECHANICS (3-0). Review of kinematics, Lagrange's equation of motion. The earth's gravitational field. Central force motion. The two body problem. The determination of orbits. The three body problem. Perturbations. PREREQUISITE: A course in dynamics.

MA 3372 DIFFERENTIAL EQUATIONS FOR OPTIMUM CONTROL (3-0). Variational equations, adjoint system of differential equations, Green's functions, Duhamel and convolution integrals. Calculus of variations, Euler equations, maximum principle, properties of extremals, region of attainability. Numerical methods for determining and correcting trajectories, particularly optimum trajectories, on a digital computer; methods of steepest ascent, variation of extremals, dynamic programming. Applications to ship routing and rocket trajectories. PREREQUISITE: MA 2121 (programming experience desirable).

MA 3393 TOPICS IN APPLIED MATHEMATICS (Credit Variable). The subject matter of this seminar will vary according to the interests of the participants. Topics will be chosen from the fields of modern optimization theory, applied functional analysis, trajectory, orbit analysis,

special functions of applied mathematics, relativity theory, or from the other fields. PREREQUISITE: Consent of Instructor.

MA 3510 FOUNDATIONS OF MATHEMATICS (3-0). Propositional and predicate calculus with proof theory and formal number theory. Godel theorems on undecidability and completeness and the Lowenheim-Skolem theorem. PREREQUISITE: Consent of Instructor.

MA 3520 SET THEORY (3-0). An intuitive development of Cantor's set theory, including a theory of cardinal and ordinal numbers with a discussion of well-ordering and the choice axiom, followed by a brief introduction to the Zermelo-Fraenkel axioms. PREREQUISITE: Consent of Instructor.

MA 3565 MODERN ALGEBRA I (3-0). Elements of set theory, equivalence relations and sets. Mappings and composition of mappings. Some elementary properties of integers, e.g., Euclidean algorithm, g.c.d., l.c.m., congruence relation. Group theory, subgroups. Normal subgroups and quotient groups. Homomorphisms, isomorphisms and automorphisms. Counting principles. PREREQUISITE: Consent of Instructor.

MA 3566 MODERN ALGEBRA II (3-0). Rings, ideals and quotient rings, Euclidean rings and polynomial rings. Linear vector spaces. Fields, extension fields, Galois groups and solvability. PREREQUISITE: MA 3565.

MA 3580 DIFFERENTIAL GEOMETRY (3-0). Curvature, evolutes and involutes, transformation groups, Lie algebras. Space curves, surfaces, geodesics and Riemannian geometry. PREREQUISITES: MA 2045 and MA 3606.

MA 3590 TOPICS IN ALGEBRA AND ANALYSIS (3-0). This course is one of variable content and is designed to meet occasional needs of groups of students interested in some particular aspects of algebra and/or analysis. Topics that might be treated: group theory, theory of numbers, theory of equations, theories of integration, et cetera. PREREQUISITE: Consent of Instructor.

MA 3591 TOPICS IN GEOMETRY (3-0). The subject matter of this seminar will vary according to the interests of the participants. Usually, the content will be topics from algebraic geometry, projective differential geometry, foundations, metric geometry. PREREQUISITE: Consent of Instructor.

MA 3605 FUNDAMENTALS OF ANALYSIS I (3-0). Elements of set theory, the real number system, and the usual topology in  $E_n$ . Properties of continuous functions. Differentials of vector-valued functions, Jacobians, and applications (implicit function, inverse function theorems, extremum problems). PREREQUISITE: Consent of Instructor.

MA 3606 FUNDAMENTALS OF ANALYSIS II (3-0). Functions of bounded variation and theory of Riemann-Stieltjes integration. Multiple and iterated integrals. Convergence theorems for sequences and series of functions. PREREQUISITE: MA 3605.

MA 3610 INTRODUCTION TO GENERAL TOPOLOGY (3-0). Topologies, bases and subbases, compactness and connectivity. Moore-Smith convergence theorems. Metrization and embedding theorems, uniform structures, Tychonoff product theorem, Alexandroff and Stone-Cech compactification. PREREQUISITE: MA 3605.

MA 3660 BOUNDARY VALUE PROBLEMS (3-0). The partial differential equations of physics and their solutions by separation of variables. Orthogonal sets of functions; Fourier series, their convergence and other properties. Applications to boundary value problems, verification and uniqueness of solutions. Continuation to include Bessel functions and Legendre polynomials. PREREQUISITE: MA 2121 or equivalent.

MA 3675 THEORY OF FUNCTIONS OF A COMPLEX VARIABLE I (3-0). Selected topics from the theory of functions of a real variable. Complex functions and analytic functions. Integration in the complex plane. Series of complex functions. Power series. Laurent series. PREREQUISITE: Consent of Instructor.

MA 3676 THEORY OF FUNCTIONS OF A COMPLEX VARIABLE II (3-0). Singularities of complex functions. Residues and contour integration. Zeros of analytic functions, factors of and infinite product representations for analytic functions. Maximum modulus theorems for analytic and harmonic functions. Conformal mapping. PREREQUISITE: MA 3675.

MA 3691 SEMINAR IN ANALYSIS (3-0). Topics in analysis. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

MA 3730 NUMERICAL ANALYSIS AND COMPUTATION (3-0). Algorithms, flow charts, and FORTRAN statements. Difference equations. Iterative procedures to solve equations and systems of equations. Linear difference equations. Quotient-difference algorithms. FORTRAN subroutines. The interpolating polynomial and its construction. Numerical differentiation and integration. Numerical solution of differential equations. PREREQUISITE: Graduate standing in engineering or sciences.

#### *Graduate Courses*

MA 4186 TENSOR ANALYSIS II (3-0). A continuation of MA 3185. Introduction to special relativity theory, with emphasis upon axiomatic and philosophical foundations. Formulation of the laws of mechanics and electromagnetism in relativistic form. Introduction to general relativity. PREREQUISITE: MA 3185 and a sound background in classical mechanics and electromagnetism.

MA 4237 ADVANCED TOPICS IN NUMERICAL ANALYSIS (4-0). The subject matter will vary according to the abilities and interests of those enrolled. PREREQUISITE: MA 3243.

MA 4362 INTRODUCTORY CONTROL AND GUIDANCE (4-0). Elements of orbits, orbit determination, gravitational harmonics due to oblateness. Equation of motion



of a rocket; integration for thrust constant. Variational and adjoint equations in trajectory determination and optimization; perturbations. Rendezvous and interception trajectories, impulse solutions, error correction. Closed form solutions for nearly circular orbits. Pitch, yaw, roll stabilization. Stable platform. Inertial guidance of airplanes and missiles. PREREQUISITE: A course in dynamics.

MA 4520 BOOLEAN ALGEBRA (3-0). A treatment of Boolean algebra as an abstract mathematical system. The interrelationships between Boolean algebra, set theory and logic are stressed through the algebra of sets and the statement calculus. Stone representation theorem for a Boolean algebra is covered in detail. PREREQUISITE: Consent of Instructor.

MA 4581 ALGEBRAIC CURVES (3-0). Algebraic varieties, Hilbert Nullstellensatz, absolute theory of varieties, normal varieties, Riemann-Roch theorem. PREREQUISITES: MA 3565 and MA 3566.

MA 4607 FUNDAMENTALS OF ANALYSIS III (3-0). Continuation of MA 3606. Line and surface integrals. Stokes' theorem, improper integrals, Fourier series and Fourier integrals. PREREQUISITE: MA 3606.

MA 4611 CALCULUS OF VARIATIONS (3-0). Bliss' differential methods, Euler equations, Weierstrass-maximum principle, Legendre conditions. Perturbation techniques, numerical procedures for determining solutions, and applications to engineering and control problems. PREREQUISITE: MA 2121 (programming experience desirable).

MA 4612 TOPICS IN NONLINEAR MATHEMATICS (3-0). Linear and nonlinear transformations. Nonlinear algebraic and transcendental equations. Nonlinear optimization; nonlinear programming and systems of inequalities. Nonlinear ordinary differential equations. Introduction to automatic control and the maximum principle. PREREQUISITE: MA 4622 or Consent of Instructor.

MA 4622 PRINCIPLES AND TECHNIQUES OF APPLIED MATHEMATICS (3-0). Generalized functions and direct operational methods for solving linear problems; Green's functions and solution of ordinary and partial differential equations; eigenvalue problems of ordinary differential equations. PREREQUISITES: MA 3047 and MA 4637 (the latter may be taken concurrently).

MA 4635 FUNCTIONS OF REAL VARIABLES I (3-0). Axiomatic set theory, development of the real numbers, semicontinuous functions, absolutely continuous functions, functions of bounded variation. Classical Lebesgue measure and integration theory in  $E_1$ , convergence theorems and  $L_p$  spaces. PREREQUISITE: MA 3606.

MA 4636 FUNCTIONS OF REAL VARIABLES II (3-0). Abstract measure and integration theory, signed measures, Radon-Nikodym theorem, Lebesgue decomposition and product measures. Daniell integrals and integral representation of linear functionals. PREREQUISITE: MA 4635.

MA 4637 INTRODUCTION TO FUNCTIONAL ANALYSIS (3-0). An introduction to Banach and Hilbert spaces, including open mapping-closed graph theorem, weak and weak\* topologies, spectral theorems for compact Hermitian operators, Hermitian bounded and normal bounded operators. PREREQUISITE: MA 4636.

MA 4662 INTEGRAL EQUATIONS (3-0). Integral equations of the first and second kinds. The Fredholm alternative. Volterra equations. Neumann series. Integral equations with symmetric kernels. Hilbert-Schmidt theory. Singular equations. Applications. PREREQUISITE: Consent of Instructor.

MA 4672 INTEGRAL TRANSFORMS (3-0). The Laplace, Fourier and Hankel transforms and their inversions. Applications to problems in engineering and physics. PREREQUISITE: MA 3172.

MA 4677 THEORY OF FUNCTIONS OF A COMPLEX VARIABLE III (3-0). Special functions of a complex variable. Analytic theory of differential equations. PREREQUISITE: MA 3676.

MA 4691 SEMINAR IN ANALYSIS (Variable). Topics to be chosen from functional analysis, integration theory, partial differential equations and differential manifolds. PREREQUISITE: Consent of Instructor.

MA 4872 TOPICS IN CALCULUS OF VARIATIONS (3-0). Recent developments in the numerical solution of problems in the calculus of variations. Foundations of numerical methods, applied to control problems. Differentials, perturbations, variational equations, adjoint system, conditions for optimum. Euler equations, maximum principle of Weierstrass and Pontryagin, the Legendre condition. Methods of solution: special variations, variation of extremals, dynamic programming. Applications in ship routing and missile control. PREREQUISITES: MA 2121, MA 3046 and computer programming or Consent of Instructor.

## PROBABILITY AND STATISTICS

### *Upper Division Courses*

PS 2111 INTRODUCTION TO PROBABILITY AND STATISTICS I (4-0). Elementary probability concepts. Finite sample outcome spaces. Discrete probability laws and their application to meteorology, operations analysis, engineering and management. Data reduction. Properties of probability laws. Conditional probability and Bayes theorem. Random variables. Selected continuous probability laws and their applications. Central limit properties. Elements of sampling and its use in statistics. PREREQUISITE: A previous course in differential calculus.

PS 2311 ELEMENTARY PROBABILITY AND STATISTICS (3-0). An introduction to probability and statistics. Methods of data summary. Tests of hypotheses and estimation. This course is limited to students in the BA/BS Program. PREREQUISITE: MA 1021 or equivalent.



PS 2321 INTRODUCTION TO PROBABILITY AND STATISTICS (3-1). An elementary treatment of probability with some statistical applications. Topics discussed are probability models, discrete and continuous random variables, moment properties, testing statistical hypotheses, and statistical estimation. PREREQUISITE: MA 1021 or equivalent.

PS 2325 INTRODUCTION TO PROBABILITY THEORY (3-1). A basic axiomatic development of probability theory. Sets and probability axioms. Discrete random variables and probability laws. Moments, Bayes theorem, law of large numbers. Some of the topics will be explored on the School's computer system.

PS 2331 ELEMENTARY PROBABILITY AND STATISTICS (4-1). Elements of the theory of probability. The classical probability distributions. Elements of statistical inference with applications in the field of the group. PREREQUISITE: MA 1100 or equivalent.

*Upper Division or Graduate Courses*

PS 3101 MANAGEMENT STATISTICS I (5-0). Elements of probability theory with emphasis on random variables and their probability distributions. Distributions of estimators of parameters. Applications of these concepts as aids in decision making. Discussion of tests of hypothesis and parameter estimation. Regression and correlation theory. Bayesian methods. Applications to management problems. PREREQUISITE: MA 2300.

PS 3102 MANAGEMENT STATISTICS II (4-1). A continuation of PS 3101. Emphasis on statistical inference applied to management problems.

PS 3112 PROBABILITY AND STATISTICS I (4-0). Discrete and continuous probability laws with engineering, meteorological, operations analysis, and systems analysis applications. Fundamental properties of probability laws and their role in assessing measurement of random events. Derived distributions. Elements of sampling and sample distributions and moments. Central limit theorems with applications. Introduction to statistical estimation. Reliability applications. PREREQUISITE: A thorough knowledge of differential and integral calculus.

PS 3113 PROBABILITY AND STATISTICS II (4-0). Confidence interval estimation and hypothesis testing. Life testing and system reliability estimation. Linear and multiple regression with application to prediction and estimation. Systems analysis pertaining to redundancy reliability, and maintainability. Selected topics in applied areas. PREREQUISITE: PS 3112 or equivalent.

PS 3205 PROBABILITY (3-0). Elements of set theory. Foundations of probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution of functions. The classical distribution functions. Joint, marginal and conditional distribution functions. Characteristic functions. Limit theorems. Introduction to random

processes. Applications to fields of interest of the class. Markov chains. PREREQUISITES: MA 2121 and MA 3172.

PS 3315 PROBABILITY AND STATISTICS (4-1). Elements of set theory. Foundations of probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution functions. Bayes theorem. The classical distributions. Expectations, propagation of error. Joint, marginal and conditional distribution functions, least squares. Limit theorems. Derivation of Poisson process. Elements of hypothesis testing and estimation. PREREQUISITE: MA 1100 or equivalent.

PS 3316 APPLIED ENGINEERING STATISTICS (3-0). Tests of hypothesis and estimation. Analysis of variance. Statistical quality control, control charts. Sampling inspection. Reliability theory and application. PREREQUISITE: PS 3315.

PS 3326 PROBABILITY AND STATISTICS (3-1). A continuation of PS 2325. Continuous random variables and their probability laws. Moments. Elements of sampling, sampling distributions and moments. Introduction to statistical point and interval estimation. Use will be made of the School's digital computer to determine, for example, probability distributions by simulation.

PS 3327 APPLIED STATISTICS (3-1). A continuation of PS 3326. Statistical inference. Correlation theory, multiple regression analysis, analysis of variance. Role of the computer in solving complex statistical problems. Use will be made of the comprehensive library of statistical programs available in the School.

PS 3332 APPLIED STATISTICS (3-0). Elements of statistical estimation and hypothesis testing. Regression analysis, selected topics in quality assurance and sampling inspection. Elementary topics in reliability theory and maintainability. PREREQUISITE: PS 3315.

PS 3335 STATISTICS I (3-0). Introduction to probability theory. Derivation and properties of principal frequency functions of discrete and continuous random variables. Joint distributions and introduction to regression and correlation. PREREQUISITE: MA 1100 or equivalent.

PS 3336 STATISTICS II (3-0). Applications of probability in statistics. Derived distributions. Estimators of parameters and their frequency functions. Mathematical expectation. Introduction to sampling theory. Applications in meteorology. PREREQUISITE: PS 3335.

*Graduate Course*

PS 4206 DECISION THEORY AND CLASSICAL STATISTICS (3-0). Testing statistical hypotheses, point estimation, interval estimation, regression analysis. Decision theoretic problem with specific attention given to minimax strategies. Bayes strategies, and admissibility. PREREQUISITE: PS 3205.

## DEPARTMENT OF MECHANICAL ENGINEERING

ROBERT EUGENE NEWTON, Professor of Mechanical Engineering; Chairman (1951)\*; B.S. in M.E., Washington Univ., 1938; M.S., 1939; Ph.D., Univ. of Michigan, 1951.

DENNIS KAVANAUGH, Professor Emeritus of Mechanical Engineering (1926); B.S., Lehigh Univ., 1914.

JOHN EDISON BROCK, Professor of Mechanical Engineering (1954); B.S.M.E., Purdue Univ., 1938; M.S.E., 1941; Ph.D., Univ. of Minnesota, 1950.

JOSEPH GILLES CANTIN, Associate Professor of Mechanical Engineering (1960); B.A.Sc., Ecole Polytechnique (Montreal), 1950; M.Sc., Stanford Univ., 1960.

VIRGIL MORING FAIRES, Professor of Mechanical Engineering (1958); B.S. in M.E., Univ. of Colorado, 1922; M.S., 1925; M.E., 1926.

ERNEST KENNETH GATCOMBE, Professor of Mechanical Engineering (1946); B.S., Univ. of Maine, 1931; M.S., Purdue Univ., 1939; Ph.D., Cornell Univ., 1944.

CECIL DUDLEY GREGG KING, Associate Professor of Mechanical Engineering (1952); B.E., Yale Univ., 1943; M.S. in M.E., Univ. of California at Berkeley, 1952.

PAUL JAMES MARTO, Assistant Professor of Mechanical Engineering (1965); B.S., Univ. of Notre Dame, 1960; M.S. in Nuc. Sci., Massachusetts Institute of Technology, 1962; Sc.D., 1965.

ROY WALTERS PROWELL, Professor of Mechanical Engineering (1946); B.S. in I.E., Lehigh Univ., 1936; M.S. in M.E., Univ. of Pittsburgh, 1943.

PAUL FRANCIS PUCCI, Professor of Mechanical Engineering (1956); B.S. in M.E., Purdue Univ., 1949; M.S. in M.E., 1950; Ph.D., Stanford Univ., 1955.

HAROLD MARSHALL WRIGHT, Professor of Mechanical Engineering (1945); B.Sc. in M.E., North Carolina State College, 1930; M.M.E., Rensselaer Polytechnic Institute 1931.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

## DEPARTMENTAL REQUIREMENTS FOR DEGREES IN MECHANICAL ENGINEERING

A specific curriculum should be consistent with the general minimum requirements for the degree as determined by the Academic Council.

Any program leading to award of a degree must be approved by the Department of Mechanical Engineering at least two quarters before completion. In general, approved programs will require more than minimum degree requirements in order to conform to the needs and objectives of the United States Navy.

## BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

1. *Entrance Requirements.* Prior to entering an approved curriculum, a student must have successfully completed college courses as follows: Mathematics through integral calculus, one year of chemistry, and one year of physics. In addition, through completed course work or examination, the student must demonstrate a knowledge of the fundamentals of engineering graphics.

2. *Mechanical Engineering Courses.* Minimum credit of 55 quarter hours in mechanical engineering courses is required. These must include the following minimum number of quarter hours in the indicated areas.

<i>Area</i>	<i>Minimum Quarter Hrs.</i>
Energy Conversion. (Includes thermodynamics, gas dynamics, heat transfer. Must include a course in power plants.) .....	15
Applied Mechanics. (Includes statics, dynamics, fluid mechanics, and vibrations.) .....	12
Mechanics of Solids and Machine Design. (Includes kinematics of machinery. Must include a course in machine design.) .....	12

3. *Other Specific Coverage.* The following minimum requirements must be met in each of the indicated disciplines.

MATHEMATICS—One course in each of the following subjects: linear algebra, differential equations, and digital computers.

ELECTRICAL ENGINEERING—12 quarter hours.

MATERIAL SCIENCE—4 quarter hours.

Some of these requirements may, with the consent of the department, be met by transfer credit.

4. *UPPER DIVISION CREDIT.* Minimum credit of 87 quarter hours in upper division or higher level courses is required.

## MASTER OF SCIENCE IN MECHANICAL ENGINEERING

1. *Undergraduate Preparation.* A candidate shall have satisfied the requirements for the degree Bachelor of Science in Mechanical Engineering. Credit requirements in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

2. *Mechanical Engineering Courses.* A minimum of 24 quarter hours of graduate credit in Mechanical Engineering is required.

3. *Courses in Other Departments.* A minimum of 8 quarter hours of graduate credit must be earned outside of the Mechanical Engineering Department.

4. *Thesis.* Completion of a thesis and its acceptance by

the department are required. For this a maximum of 6 quarter hours of graduate credit may be allowed toward satisfaction of the school requirement of 40 quarter hours. The thesis credit may not be used to satisfy any of the requirements of paragraphs 2 and 3.

## MECHANICAL ENGINEERING

### *Upper Division Courses*

ME 2101 ENGINEERING THERMODYNAMICS (3-2). (May be taught as AE 2401.) The fundamental laws of thermodynamics; equations of state; thermodynamic properties of substances, including qualitative microscopic viewpoint; entropy; irreversibility and availability; analysis of gas cycles with emphasis on the Brayton cycle. TEXT: Faïres, *Thermodynamics*. PREREQUISITE: MA 1100.

ME 2102 MECHANICAL ENGINEERING THERMODYNAMICS (4-0). A continuation of ME 2101. Application of thermodynamic principles to marine power plant equipment; the Rankine cycle; gas-vapor mixtures; reversed cycles; combustion with dissociation problems. TEXT: Faïres, *Thermodynamics*. PREREQUISITE: ME 2101.

ME 2110 APPLIED THERMODYNAMICS (4-2). Introduction to engineering thermodynamics with emphasis on application of thermodynamic principles to marine power plants. Review of first and second laws of thermodynamics, work and heat, processes, gas and vapors, cycles and plants. PREREQUISITE: MA 1100.

ME 2120 ELEMENTS OF ENGINEERING THERMODYNAMICS (3-2). The fundamental concepts of thermodynamics; thermodynamic properties and equations of state; the first law of thermodynamics; entropy and the second law of thermodynamics; cycle analysis with some applications. TEXT: Faïres, *Thermodynamics of Heat Power*. PREREQUISITE: PH 1015.

ME 2201 MECHANICS OF FLUIDS I (4-2). Mechanical properties of fluids, hydrostatics, buoyancy and stability analysis; energy considerations in steady flow; principles of impulse—momentum and dynamic forces; dimensional analysis and similitude; viscous effects, laminar and turbulent flow; fundamentals of boundary layer theory and potential flow; fluid flow measurements; analysis of fluid machinery; associated laboratory experiments and problem work. TEXT: Streeter, *Fluid Mechanics*, 4th ed. PREREQUISITES: MA 1100 and ME 2502.

ME 2220 HEAT TRANSFER AND GAS DYNAMICS (4-2). The fundamental heat transfer mechanisms; conduction, convection and radiation; and the use of various techniques in problem solution. Heat exchanger analysis. Fundamentals of one-dimensional compressible flow including effects of area change, normal shock and friction. TEXTS: Giedt, *Principles of Engineering Heat Transfer*; Shapiro, *The Dynamics and Thermodynamics of Compressible Flow*. PREREQUISITES: ME 2101 and ME 2201.

ME 2410 MECHANICAL ENGINEERING LAB I (1-3). Fundamentals of mechanical measurements, resistance strain gages, transducers and instrumentation systems, pressure, temperature and flow measurements; dynamic response characteristics. TEXT: Beckwith and Buck, *Mechanical Measurements*. PREREQUISITES: ME 2102, ME 2201 and ME 2601.

ME 2420 MECHANICAL ENGINEERING LAB II (2-3). A continuation of ME 2410 for students participating in the BS program; application of measurement techniques using experiments in thermodynamics, mechanics of solids, heat transfer and fluid flow. TEXT: Beckwith and Buck, *Mechanical Measurements*. PREREQUISITE: ME 2410.

ME 2501 MECHANICS I (4-0). Laws of statics. Force systems, equilibrium, simple structures, distributed forces, friction. Kinematics. Newton's law. Particle applications. TEXT: Beer and Johnston, *Vector Mechanics*. PREREQUISITE: A course in vector algebra (may be concurrent).

ME 2502 MECHANICS II (3-0). Work and energy. Impulse and momentum. Kinematics of rigid bodies. Moment of inertia. Axial rotation and plane motion of rigid bodies. TEXT: Beer and Johnston, *Vector Mechanics*. PREREQUISITE: ME 2501.

ME 2562 SPACE FLIGHT DYNAMICS (4-0). Review of particle dynamics. Rocket propulsion. Kepler's Laws. Ballistic missiles, artificial satellites, space probes. TEXTS: Meriam, *Dynamics*; Van de Kamp, *Elements of Astrodynamics*. PREREQUISITES: Analytic geometry, differential and integral calculus, mechanics.

ME 2601 MECHANICS OF SOLIDS I (3-2). Stress, strain, Hooke's law, tension and compression, shearing stresses, connections, thin vessels, torsion, statics of beams, stresses in beams, deflections of beams, combined loadings and combined stresses, columns. Strain energy, impact, simple indeterminate structures. Supporting laboratory work. TEXT: Timoshenko and Young, *Elements of Strength of Materials*. PREREQUISITES: ME 2501 and MA 1100.

ME 2641 STRUCTURAL MECHANICS (4-0). Review of statics of rigid bodies and applications to determinate structures. Stress, strain, Hooke's law, tension and compression, shearing stresses. Connections, thin vessels, torsion. Statics of beams, flexural stresses and deformations, numerical methods. Simple indeterminate structures. Combined loadings and combined stresses. Columns. TEXT: Timoshenko and Young, *Elements of Strength of Materials*. PREREQUISITE: A course in mechanics.

ME 2721 MACHINE DESIGN I (3-2). Material selection, tolerances and allowances, variable loads and stress concentration, screw fastenings, springs, combined stresses, theories of failure, shafts, keys and couplings. TEXTS: Faïres *Design of Machine Elements*; Timoshenko, *Strength of Materials*. PREREQUISITE: ME 3621.

ME 2722 MACHINE DESIGN II (2-4). Journal and plane surface bearings, ball and roller bearings, spur, helical, bevel and worm gearing, flexible power transmitting ele-



ments, brakes and clutches. TEXT: Faires, *Design of Machine Elements*. PREREQUISITE: ME 2721.

ME 2901 INDIVIDUAL STUDY IN MECHANICAL ENGINEERING (Hours to be arranged). Directed individual study by a student whose background or future plans require additional or exceptional treatment of material at the undergraduate level. PREREQUISITE: Permission of Department Chairman.

#### *Upper Division or Graduate Courses*

ME 3202 MECHANICS OF FLUIDS II (3-0). Application of the first and second laws of thermodynamics and the equation of state of a perfect gas to compressible flows. Physical differences between subsonic and supersonic flow. One dimensional isentropic flow. Normal shock waves. Adiabatic flow in constant area ducts with friction. Flow in ducts with heating or cooling. Generalized one-dimensional continuous flow. Oblique shocks. TEXT: Shapiro, *The Dynamics and Thermodynamics of Compressible Flow*. PREREQUISITES: ME 2101 and ME 2201.

ME 3210 HEAT TRANSFER (4-2). Elementary treatment of the principles of engineering heat transfer; steady-state conduction in one and two dimensions, unsteady-state conduction, principles of forced and natural convection, thermal radiation, condensation, boiling, and heat exchanger analysis. Use of the thermal circuit, analog, numerical, and graphical techniques. Laboratory experiments. TEXT: Holman, *Heat Transfer*. PREREQUISITES: ME 2101, ME 4203, and MA 3132.

ME 3310: MARINE POWER SYSTEMS ANALYSIS (2-4). Preliminary planning of marine power plants. Project work involving estimation of hull, main engine, and auxiliary power requirements. Inter-relationship of components, heat balances and flow diagrams, computation of ship and plant performance indices, preliminary investigation of various major equipment items. TEXTS: Seward, *Marine Engineering, Vols. I and II*; Church, *Steam Turbines, 3rd ed.* PREREQUISITES: ME 2220, ME 2102, and ME 2201.

ME 3320 MARINE POWER SYSTEMS ANALYSIS (2-4). Preliminary design planning, involving project work, of ship propulsion systems. Hull selection and estimation of hull power requirements. Estimation of main engine and auxiliary power requirements, inter-relationship of components, heat balances, flow diagrams, computation and presentation of ship and plant performance indices. Preliminary investigation of major equipment items including steam generators, turbines and condensers. Seminars and field trips on occasion. TEXTS: Seward, *Marine Engineering, Vols. I and II*; Church, *Steam Turbines, 3rd ed.* PREREQUISITES: ME 2102, ME 2201 and ME 3210.

ME 3330 NUCLEAR POWER FUNDAMENTALS (4-0). An introduction to nuclear reactor principles intended for other than mechanical engineering students. Essential elements of neutron physics, reactor physics, and reactor control. Materials for reactors, reactor shielding and reactor types. Discussion of reactors including thermal and hy-

draulic problems. TEXT: King, *Nuclear Power Systems*. PREREQUISITE: PH 2810.

ME 3340 NUCLEAR POWER SYSTEMS (4-0). Fundamentals of nuclear reactor physics, control and shielding. Engineering considerations in nuclear reactors including problems in core thermal and hydraulic design and shielding design. Principal reactor types. Nuclear power cycles. TEXT: King, *Nuclear Power Systems*. PREREQUISITES: ME 2220 and PH 2810.

ME 3430 MECHANICAL ENGINEERING LAB II (2-3). A continuation of ME 2410 for students participating in the MS program; application of measurement techniques using experiments in thermodynamics, mechanics of solids, heat transfer and fluid flow. TEXT: Beckwith and Buck, *Mechanical Measurements*. PREREQUISITES: ME 2410 and ME 4511.

ME 3521 MECHANICAL VIBRATIONS (3-2). Free and forced vibration of linear systems. Matrix methods. Vibration isolation and absorbers, torsional vibration, continuous systems. Laboratory experiments with prototype and simulated systems. TEXT: Den Hartog *Mechanical Vibrations*. PREREQUISITES: ME 3621, ME 2502 and MA 2121.

ME 3611 MECHANICS OF SOLIDS II (4-0). Further elastic analysis of statically indeterminate structures, beam columns, curved beams, unsymmetrical bending, shear center, beams on elastic foundations, plates and shells, thick walled cylinders, rotating discs, and elementary thermal stresses. TEXT: Timoshenko, *Strength of Materials, Parts I and II*. PREREQUISITES: ME 2601 and MA 2121.

ME 3621 MECHANICS OF SOLIDS II (4-0). Statically indeterminate problems in bending, symmetrical beams of variable cross section, beams of two materials, unsymmetrical bending, curved bars, beams with combined axial and lateral loads, thin plates and shells, rotating discs, torsion in noncircular sections. TEXT: Timoshenko, *Strength of Materials, Parts I and II*. PREREQUISITES: ME 2601 and MA 2121.

ME 3642 STRUCTURAL THEORY (4-0). Stability and determinacy of simple structures. Energy methods. Matrix methods. Flexibility and stiffness methods. Dynamic response of systems having one, two, and many degrees of freedom. TEXTS: Gere and Weaver, *Analysis of Framed Structures*; Rogers, *Dynamics of Framed Structures*. PREREQUISITES: ME 2641 and MA 2121.

ME 3711 MACHINE DESIGN I (3-2). First of a two course sequence. Studies entailing design projects based upon fits, tolerances, allowances, material selection, stress concentration, kinematics, bearings, shafts, screws, belts, chains, brakes, clutches and cams. TEXT: Faires, *Design of Machine Elements, 4th ed.* PREREQUISITE: ME 3611.

ME 3712 MACHINE DESIGN II (3-4). Continuation of ME 3711; springs, gearing, and advanced problems. Machine design projects which require complete design studies. TEXT: Faires, *Design of Machine Elements, 4th ed.* PREREQUISITES: ME 3711 and ME 4511.

*Graduate Courses*

ME 4120 DIRECT ENERGY CONVERSION (3-0). Introduction to the principles of direct energy conversion employing thermoelectric generators, photovoltaic generators, thermionic generators, magnetohydrodynamic power generators, and fuel cells. TEXT: Angrist, *Direct Energy Conversion*. PREREQUISITES: ME 2101, ME 2201, EE 2101 and MA 2121.

ME 4203 MECHANICS OF FLUIDS III (4-0). Potential flow theory, linearized compressible flow, viscous flow and boundary layer theory. TEXTS: Shapiro, *Thermodynamics and Dynamics of Compressible Flow, Vols. I and II*; Li and Lam, *Principles of Fluid Mechanics*. PREREQUISITES: ME 3202 and MA 3132.

ME 4351 NUCLEAR ENGINEERING I (4-0). Fundamentals of nuclear reactor physics. Nuclear reactions and radiations. Diffusion and slowing down of neutrons. Reactor theory: the steady state and the unsteady state control of nuclear reactors. TEXTS: Glasstone and Sesonske, *Nuclear Reactor Engineering*; Glasstone and Edlund, *The Elements of Nuclear Reactor Theory*; King, *Nuclear Power Systems*. PREREQUISITE: PH 2810.

ME 4352 NUCLEAR ENGINEERING II (3-3). Energy removal from nuclear reactor cores including thermal and hydraulic design considerations. Fuel cycles. Reactor materials. Shielding of nuclear reactor systems. Elementary preliminary design of nuclear power plants. TEXTS: Glasstone and Sesonske, *Nuclear Reactor Engineering*; King, *Nuclear Power Systems*; Etherington, *Nuclear Engineering Hand-*

*book*. PREREQUISITES: ME 4351, ME 2201, ME 3210 and ME 2102.

ME 4511 VIBRATION THEORY (3-2). Transient and steady-state motion of mechanical systems. Lagrange's equations. Multi-degree of freedom systems. Vibration of continuous systems. Applications to shock problems. Introduction to nonlinear systems. Supporting laboratory experiments. TEXT: Thomson, *Vibration Theory and Applications*. PREREQUISITES: ME 2502 and EE 3498.

ME 4512 ADVANCED DYNAMICS (4-0). Intensive treatment of vector kinematics. Orbital mechanics. Inertial tensor. Rigid body kinetics. Jacobian elliptic functions. TEXTS: Yeh and Abrams, *Mechanics of Solids, Vol. I*; Synge and Griffith, *Principles of Mechanics*. PREREQUISITE: ME 4511.

ME 4612 MECHANICS OF SOLIDS III (4-0). Elements of theory of elasticity. Stress tensor and theories of failure. Torsion of noncircular sections. Plastic analysis. Matrix methods in structural analysis. Brittle fracture. TEXTS: Timoshenko, *Strength of Materials, Part II*; Timoshenko and Goodier, *Theory of Elasticity*; Parker, *Brittle Behavior of Engineering Structures*. PREREQUISITES: MA 3132 and ME 3611.

ME 4902 ADVANCED STUDY IN MECHANICAL ENGINEERING (Hours to be arranged.) Directed advanced study in mechanical engineering on a subject of mutual interest to student and staff member. May be repeated for credit with a different topic. PREREQUISITE: Permission of Department Chairman.

## DEPARTMENT OF METEOROLOGY AND OCEANOGRAPHY

GEORGE JOSEPH HALTNER, Professor of Meteorology; Chairman (1946)\*; B.S., College of St. Thomas, 1940; Ph.M., Univ. of Wisconsin, 1942; Ph.D., 1948.

DONALD CHIN, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., Rutgers Univ., 1952; M.S., Cornell Univ., 1953; M.S., Naval Postgraduate School, 1964.

MAURICE BEVERLY DANARD, Associate Professor of Meteorology (1967); B.A.Sc., Univ. of British Columbia, 1957; M.A., Univ. of Toronto, 1959; Ph.D., Univ. of Chicago, 1963.

WARREN WILSON DENNER, Assistant Professor of Oceanography (1964); B.S., Portland State College, 1961; M.S., Oregon State Univ., 1963.

WILLIAM DWIGHT DUTHIE, Distinguished Professor and Professor of Meteorology (1945); B.A., Univ. of Washington, 1935; M.S., 1937; Ph.D., Princeton Univ., 1940

WILLIAM LAWRENCE GATES, Professor of Meteorology and Oceanography (1966); S.B., Massachusetts Institute of Technology, 1950; S.M., 1951; Sc.D., 1955.

CLAUDE FINLEY GILES, Commander, U.S. Navy; Instructor in Meteorology; B.S., Parks College of St. Louis Univ., 1948; B.S. in Meteorology, Naval Postgraduate School, 1955.

THEODORE GREEN, III, Assistant Professor of Oceanography (1965); A.B., Amherst College, 1959; M.S., Stanford Univ., 1961; Ph.D., 1965.

EUGENE CLINTON HADERLIE, Associate Professor of Oceanography (1965); A.B., Univ. of California at Berkeley, 1943; M.A., 1948; Ph.D., 1950.

GLENN HAROLD JUNG, Professor of Oceanography (1958); B.S., Massachusetts Institute of Technology, 1949; M.S., 1952; Ph.D., Texas Agricultural and Mechanical College, 1955.

TIRUVALAM NATARAJAN KRISHNAMURTI, Associate Professor of Meteorology (1967); B.S., St. Stephens College, New Delhi, 1951; M.S., Andhra Univ., Waltair, India, 1951; Ph.D., Univ. of Chicago, 1959.

FRANK LIONEL MARTIN, Professor of Meteorology (1947); B.A., Univ. of British Columbia, 1936; M.A., 1938; Ph.D., Univ. of Chicago, 1941.

ROBERT JOSEPH RENARD, Associate Professor of Meteorology (1952); M.S., Univ. of Chicago, 1952.

WILLIAM STEPHENS, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., Naval Academy, 1955; M.S., Naval Postgraduate School, 1961.

DONALD ALLEN STILL, Commander, U.S. Navy; Instructor in Oceanography; B.S., Oregon State College, 1950; Scripps Institution of Oceanography, 1955.

DAVID WAYNE STUART, Associate Professor of Meteorology (1966); B.S., Univ. of California at Los Angeles, 1955; M.A., 1957; Ph.D., 1962.

CHARLES LUTHER TAYLOR, Associate Professor of Meteorology (1954); B.S., Pennsylvania State Univ., 1942; M.S., 1947.

WARREN CHARLES THOMPSON, Professor of Oceanography (1953); B.A., Univ. of California at Los Angeles, 1943; M.S., Scripps Institution of Oceanography, 1948; Ph.D., Texas Agricultural and Mechanical College, 1953.

WILLEM VAN DER BIJL, Associate Professor of Meteorology (1961); B.Sc., Free Univ. of Amsterdam, 1941; M.Sc., 1943; Ph.D., State Univ., Utrecht, 1952.

JOSEPH JOHN VON SCHWIND, Associate Professor of Oceanography (1967); B.S., Univ. of Wisconsin, 1952; M.S., Univ. of Utah at Salt Lake City, 1960.

JACOB BERTRAM WICKHAM, Associate Professor of Oceanography (1951); B.S., Univ. of California at Berkeley, 1947; M.S., Scripps Institution of Oceanography, 1949.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

## DEPARTMENTAL REQUIREMENTS FOR DEGREES IN METEOROLOGY AND OCEANOGRAPHY

### BACHELOR OF SCIENCE IN METEOROLOGY

1. The degree of Bachelor of Science in Meteorology requires completion of:

- Mathematics courses including differential and integral calculus, vectors, digital computers, and numerical methods.
- Thirty-six quarter hours in meteorology courses including the basic sequences in dynamic, physical and synoptic meteorology.
- An acceptable research paper.

### MASTER OF SCIENCE IN METEOROLOGY MASTER OF SCIENCE IN OCEANOGRAPHY

1. Entrance to a program leading to a Master of Science degree in Meteorology or Oceanography requires mathematics through differential and integral calculus and a minimum of one year of college physics. The oceanography program additionally requires a year of college chemistry.

#### 2. General Requirements:

The degree of Master of Science in Meteorology or Oceanography requires completion of:

- Mathematics courses in vector analysis, partial differential equations, and application of numerical methods and computers to the solution of partial differential equations.
- An acceptable thesis.



### 3. Specific Requirements:

a. The degree of Master of Science in Meteorology requires completion of:

- 1) Thirty-five quarter hours of graduate meteorology courses of which eighteen hours must be in the 4000 series.
- 2) The basic sequences of graduate courses in the fields of dynamic, physical, and synoptic meteorology.

4. The degree of Master of Science in Oceanography requires completion of sixty-five quarter hours of graduate oceanography and meteorology courses of which thirty hours must be in the oceanography 4000 course series.

## METEOROLOGY

### Lower Division Courses

MR 1105 WEATHER CODES—OBSERVATIONS—PLOTING (0-3). Acquaintance with weather codes and observation stressing utility and application; introduction to analysis of scalar fields stressing basic techniques and continuity. TEXTS: WBAN Manuals for Synoptic, Radiosonde and Upper Wind Codes; International Cloud Atlas; Weather Station Index Manual; departmental notes. PREREQUISITE: MR 2200.

### Upper Division Courses

MR 2100 METEOROLOGY (3-0). The principles of meteorology and the effects of weather phenomena on naval operations. Topics include: structure of the atmosphere; weather elements; pressure and winds; theory of air masses and fronts; tropical storms; sources of weather information; sea and swell conditions; principles of weather map analysis and forecasting. TEXT: Petterssen, *Introduction to Meteorology*. PREREQUISITE: None.

MR 2200 INTRODUCTION TO METEOROLOGY (3-0). A general course which treats descriptively the composition and vertical structure of the atmosphere, physical processes, general circulation, air masses, fronts, cyclones and anticyclones, tropical disturbances, storms, and hurricanes. TEXTS: Petterssen, *Introduction to Meteorology*; AMS Glossary of Meteorology. PREREQUISITE: None.

MR 2205 METEOROLOGY FOR OCEANOGRAPHERS (0-4). A laboratory course in weather observations, codes, and the technique of synoptic analysis. The emphasis is on the surface chart and the determination of meteorological parameters for application to problems in oceanography. TEXTS: WBAN Manual for Synoptic Codes; Weather Station Index Manual; departmental notes; ASWEPS Series Manual, Vol. 3. PREREQUISITE: MR 2200 concurrently.

MR 2220 WEATHER MAP ANALYSIS (4-0). Graphical arithmetic; techniques of scalar and frontal analysis; evaluation of surface and upper-air data; structure and behavior of extratropical cyclones; stability analysis and air masses; space/time cross sections. TEXTS: Berry, Bollay, Beers, *Handbook of Meteorology*; departmental notes. PREREQUISITES: MR 1105, MR 2200, MR 2411 or MR 3411; MR 3301 or MR 4321 concurrently.

MR 2225 WEATHER MAP ANALYSIS LABORATORY (0-6). Laboratory course taught in conjunction with MR 2220. Graphical arithmetic practice in upper-air and surface analysis; analysis of upper-air soundings, and vertical space/time cross-sections; introduction of meteorological satellite observations, local forecasting techniques and mesoscale synoptic analysis. TEXTS: Berry, Bollay, Beers, *Handbook of Meteorology*; departmental notes. PREREQUISITES: MA 1105, MR 2200.

MR 2279 OPERATIONAL METEOROLOGY (1-6). Instruction and laboratory practice in operational functions and responsibilities of the Naval Weather Service. TEXTS: Selected publications of the Air Systems Command, Air Weather Service, and Naval Weather Research Facility; departmental notes. PREREQUISITE: MR 3255.

MR 2410 METEOROLOGICAL INSTRUMENTS (3-2). The application of the basic principles of mechanics, heat, electricity, sound, and optics to meteorological instruments. Design and operation of meteorological instrumentation employed by the Navy with special emphasis on electronic and satellite developments. TEXTS: Middleton and Spilhaus, *Meteorological Instruments*; selected papers and departmental notes. PREREQUISITE: MA 1115 concurrently.

MR 2411 INTRODUCTION TO THERMODYNAMICS OF METEOROLOGY (4-0). A treatment of elementary thermodynamics and its application to meteorology with particular emphasis on thermodynamic charts and diagrams. Theories of condensation and precipitation processes. Geopotential determinations and instability criteria. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology*. PREREQUISITE: MA 1116 concurrently.

MR 2510 CLIMATOLOGY (4-2). Statistical evaluation of meteorological elements in theory and in practice. (Frequency distributions. Correlation and regression.) Verification systems. Techniques of objective forecasting. Classification of climates. TEXTS: Conrad and Pollak, *Methods in Climatology*; Schaum (Spiegel), *Statistics*; departmental notes. PREREQUISITE: MA 1116 concurrently.

### Upper Division or Graduate Courses

MR 3230 TROPOSPHERIC AND STRATOSPHERIC METEOROLOGY (4-0). Observation, computation, analysis, and synoptic interpretation of tropospheric and stratospheric data (to 10 mb) with emphasis on the middle and high latitude aspects of satellite meteorology, jet streams, tropopause, vertical motion, hydrometeors, and related numerical products. TEXTS: Widger, *Meteorological Satellites*; Riehl, *Jet Streams of the Atmosphere*; Craig, *The Upper Atmosphere*; Webb, *Structure of the Stratosphere and Mesosphere*; various U.S. Navy, Environmental Science Services Administration and Air Weather Service publications; reprints and departmental notes. PREREQUISITES: MR 2220; MR 4322 or MR 3302 concurrently.

MR 3235 TROPOSPHERIC AND STRATOSPHERIC METEOROLOGY LABORATORY (0-9). Practice in the meso- and synoptic scale analysis of parameters considered in MR 3230 with emphasis on objectivity, interrelation-

ships, and application to forecast problems. TEXTS: Widger, *Meteorological Satellites*; Riehl, *Jet Streams of the Atmosphere*; Craig, *The Upper Atmosphere*; various U.S. Navy, Environmental Science Services Administration, and Air Weather Service publications; reprints and departmental notes. PREREQUISITE: MR 2225; MR 3230 concurrently.

MR 3250 TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY (3-0). The general circulation and air masses of the Southern Hemisphere; climatology and synoptic models in the tropics; analysis and forecasting tropical weather systems with emphasis on cyclones and meteorological satellite observations. TEXTS: Berry, Bollay, Beers, *Handbook of Meteorology*; Riehl, *Tropical Meteorology*; Harding and Kotsch, *Heavy Weather Guide*; departmental notes, reprints. PREREQUISITES: MR 4322 or MR 3302, MR 3230.

MR 3255 TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY LABORATORY (0-6). Laboratory course associated with MR 3250. Contour (isobaric), streamline, and isotach analysis and forecasting with emphasis on climatology, tropical cyclones, and meteorological satellite observations. TEXTS: Berry, Bollay, Beers, *Handbook of Meteorology*; Riehl, *Tropical Meteorology*; reprints and departmental notes. PREREQUISITES: MR 3235; MR 3250 concurrently.

MR 3260 PROGNOSTIC CHARTS AND EXTENDED FORECASTING (3-0). Subjective and objective methods, both kinematical and dynamical, of constructing prognostic charts, upper-air and surface, with greater emphasis on the latter; graphical numerical techniques; interpretation and alteration of computer-generated prognoses. Extended forecasting by weather type methods; interpretation of National Meteorological Center extended forecasts. TEXTS: George, *Weather Forecasting for Aeronautics*; Environmental Science Services Administration and Fleet Numerical Weather Facility Manuals; departmental notes. PREREQUISITES: MR 4323 or MR 3303 concurrently.

MR 3265 PROGNOSTIC CHARTS AND EXTENDED FORECASTING LABORATORY (0-6). Laboratory course taught in conjunction with MR 3260. Extended analysis; practice in construction and interpretation of prognostic charts. Weather typing; interpretation of National Meteorological Center extended forecasts and charts. TEXTS: George, *Weather Forecasting for Aeronautics*; Environmental Science Services Administration and Fleet Numerical Weather Facility Manuals; departmental notes. PREREQUISITES: MR 3235; MR 3260 concurrently.

MR 3301 FUNDAMENTALS OF DYNAMIC METEOROLOGY I (4-0). Equations of motion; wind types; trajectories and streamlines; vertical variation of wind; friction, surface and spiral layers; continuity and tendency equations; mechanism of pressure changes, vorticity and divergence equations. TEXT: Haltiner and Martin *Dynamical and Physical Meteorology*. PREREQUISITES: MA 2181, MR 2411.

MR 3302 FUNDAMENTALS OF DYNAMIC METEOROLOGY II (4-0). Simple types of wave motion, filtering; objective analysis and numerical prediction; barotropic and baroclinic models; baroclinic instability; vertical velocity; finite differencing relaxation; numerical errors. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology*; departmental notes. PREREQUISITE: MR 3301.

MR 3303 COMPUTER METEOROLOGY (3-0). Continuation of MR 3302; Computer products of Fleet Numerical Weather Facility and other groups; pressure-height, temperature, cloud, ocean wave, and clear-air turbulence, forecasting, etc. TEXT: U.S. Naval Weather Service Manual for Computer Products and departmental notes. PREREQUISITES: MR 3302, CS 3111 or equivalent.

MR 3403 INTRODUCTION TO ENERGY-TRANSFER PROCESSES (4-0). Properties of radiating matter in general; solar and terrestrial radiation and their effects on temperature distribution; the heat budget; structure of the wind in the friction layer and its significance in turbulent transfer; air-mass modification, forecasting the micrometeorological variables; interpretation of satellite radiation measurements from thermodynamic and heat budget considerations. TEXTS: Haltiner and Martin, *Dynamical and Physical Meteorology*; departmental notes. PREREQUISITE: MR 3302.

MR 3411 METEOROLOGICAL THERMODYNAMICS (4-0). The physical variables; equations of state; first law of thermodynamics; properties of gases, water, and moist air; theories of condensation and precipitation processes; cloud physics; meteorological thermodynamic diagrams; air-mass identification indices; geopotential determinations; instability phenomena and criteria. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology*. PREREQUISITE: MA 2121 concurrently.

MR 3510 STATISTICAL CLIMATOLOGY (4-2). Statistical evaluation of meteorological elements in theory and in practice. (Frequency distribution, correlation and regression, analysis of variance, and time series analysis.) Verification systems. Techniques of objective forecasting. Classification of climates. TEXTS: Barger, *Climatology at Work*; Panofsky and Brier, *Some Applications of Statistics to Meteorology*; departmental notes. PREREQUISITE: MA 1100 concurrently.

MR 3900 SEMINAR IN METEOROLOGY (2-0). Students present original research or prepare summaries of recent findings in the field of meteorology and present synopses for group discussion. PREREQUISITE: None.

#### Graduate Courses

MR 4321 DYNAMIC METEOROLOGY I (4-0). Equations of motion; coordinate systems and mapping; wind types; baroclinicity; vertical variation of wind; friction; diffusion of momentum; surface and spiral layers; continuity and tendency equations; structure of pressure systems; vorticity and divergence equations. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology*; departmental notes. PREREQUISITES: MA 3181, MR 3411.



MR 4322 DYNAMIC METEOROLOGY II (4-0). Scale analysis; perturbation method; solutions of equations of motion for simple sound, gravity, and synoptic waves; filtering; baroclinic and barotropic instability; energy equations; integral constraints. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology*; departmental notes. PREREQUISITE: MR 4321.

MR 4323 NUMERICAL WEATHER PREDICTION (4-2). Objective analysis; barotropic and baroclinic models; vertical velocity; finite-difference equations; computational instability; boundary conditions; relaxation techniques, inclusion of heat, friction, and moisture; energetic and general circulation models. TEXT: Thompson, *Numerical Weather Analysis and Prediction*; departmental notes. PREREQUISITES: MR 4322, MA 3243 concurrently.

MR 4412 HEAT TRANSFER PROCESSES (4-0). Black bodies and their properties; the fundamental laws of radiation flux transfer both in beam and diffused form, methods of terrestrial-flux computations by numerical methods with application of sounding data; interpretation of satellite radiation measurements both in terrestrial and solar regions. Surface-layer heat and water-vapor transports by turbulence; and stability effects upon such transports including that of momentum; eddy-spectral analysis. The heat budget of the atmosphere. TEXTS: Elsasser and Culbertson, *Atmospheric Radiation Tables*; Lumley and Panofsky, *The Structure of Atmospheric Turbulence*. PREREQUISITE: MR 4321 concurrently.

MR 4422 UPPER ATMOSPHERE PHYSICS (3-0). Composition, temperature, and wind above 30 km. Physics and chemistry of ozonosphere and ionosphere. Atmospheric tides, earth's magnetic field, airglow, Van Allen belts. TEXTS: Craig, *The Upper Atmosphere*; Massey and Boyd, *The Upper Atmosphere*; departmental notes. PREREQUISITE: MR 4412.

MR 4900 SEMINAR IN METEOROLOGY (2-0). Students present results of their thesis work for group discussion. PREREQUISITE: Preparation of Master's degree thesis concurrently.

## OCEANOGRAPHY

### Upper Division Courses

OC 2110 INTRODUCTION TO OCEANOGRAPHY (3-0). An introductory course treating physical and chemical properties of sea water, submarine geology, and marine biology; the heat budget of the oceans; water masses and general circulation; currents, waves, and tides. TEXTS: Pickard, *Descriptive Physical Oceanography*; Coker, *This Great and Wide Sea*. PREREQUISITE: None.

### Upper Division or Graduate Courses

OC 3220 DESCRIPTIVE OCEANOGRAPHY (3-0). Properties of sea water; water masses, currents, and three-dimensional circulation in all oceans; distribution of temperature, salinity, and oxygen; temperature-salinity relationships. TEXTS: Sverdrup, Johnson and Fleming, *The Oceans*; selected references. PREREQUISITE: OC 2110.

OC 3260 SOUND IN THE OCEAN (3-0). Designed for students in the meteorology curricula. A brief introduction to physics of underwater acoustics followed by detailed discussion of oceanographic factors affecting sound transmission in the ocean including absorption, reflection from the surface and from the bottom, refraction, scattering, and ambient noise. TEXT: Selected references. PREREQUISITE: OC 2110.

OC 3320 GEOLOGICAL OCEANOGRAPHY (3-3). Physiography of the sea floor, especially continental shelves and slopes, submarine canyons, coral reefs, and the deep-sea floor; properties and distribution of sediments and rates of deposition; structure and origin of the ocean basins. TEXTS: Shepard, *Submarine Geology*, 2nd ed.; Gilluly, Waters, and Woodford, *Principles of Geology*, 2nd ed. PREREQUISITE: OC 2110.

OC 3420 BIOLOGICAL OCEANOGRAPHY (3-3). General biological principles; the sea as an environment for life; major plant and animal groups in the sea; plankton and food cycles; primary productivity; boring and fouling organisms; bioacoustics, bioluminescence, and deep scattering layers; dangerous marine organisms; physiology of shallow water diving. Laboratory work and field trips dealing with marine organisms. TEXTS: Russell and Yonge, *The Seas*; Hedgpeth, *Seashore Life of the San Francisco Bay Region and the Coast of Northern California*. PREREQUISITE: OC 2110.

OC 3520 CHEMICAL OCEANOGRAPHY (3-2). Basic chemistry of solutions; chemical composition of the oceans (dissolved solids, gases, nutrients, etc.); distribution of constituents in the ocean; analytical methods used in chemical oceanography; carbonate, nutrient, and other cycles in the sea; desalination; corrosion; geochemistry. TEXT: Strickland and Parsons, *Methods in Chemical Oceanography*. PREREQUISITES: OC 2110, CH 1001 or CH 2001 or equivalent.

OC 3601 OCEAN WAVE FORECASTING (3-0). Statistical and spectral properties of ocean waves; the generation, propagation, and attenuation of surface wind waves in deep water; spectral and other forecasting techniques; wave observations and analysis of data. TEXTS: Kinsman, *Wind Waves*; I.O. Pub. 603. PREREQUISITE: OC 4211.

OC 3605 OCEAN WAVE FORECASTING LABORATORY (0-6). Laboratory course taught in conjunction with OC 3601. Exercises in wave observation, the analysis of wave records, forecasting of seas generated under various synoptic weather conditions, and forecasting of swell. TEXT: I.O. Pub. 603. PREREQUISITE: OC 3601 concurrently.

OC 3611 OCEAN WAVE AND SURF FORECASTING (2-0). Course designed for students in the meteorology curricula. Statistical and spectral properties of waves; wave observations and analysis of wave records; the generation, propagation, and attenuation of sea and swell; techniques used in the forecasting of sea and swell; transformation of waves in shallow water. TEXT: H.O. Pub. 603 and H.O. Pub. 234. PREREQUISITE: OC 2110.



OC 3615 OCEAN WAVE AND SURF FORECASTING LABORATORY (0-6). Laboratory course taught in conjunction with OC 3611. Exercises in forecasting sea and swell generated under various synoptic weather conditions and in surf forecasting. TEXT: H.O. Pub. 603 and H.O. Pub. 234. PREREQUISITE: OC 3611 concurrently.

OC 3616 OCEANOGRAPHIC FORECASTING (3-0). Space and time variation of ocean density structure and associated parameters; behavior of vertical and horizontal temperature gradients; development of synoptic forecasting techniques applied to the upper ocean; air-sea interaction; advection and mixing effects on ocean density structure. Interpretation in terms of sound propagation paths and sonar range. TEXTS: James, *Antisubmarine Warfare Environmental Prediction System Manual No. 5*; selected publications. PREREQUISITES: OC 3260; OC 4253 concurrently or MR 2411.

OC 3621 OCEANOGRAPHIC FORECASTING LABORATORY (0-4). Laboratory exercises illustrate principles developed in OC 3616 using actual air and ocean data, available forecasting techniques (ASWEPS, and others), and range manuals. Forecasting of sea surface temperature, mixed-layer depth, and sonar range. TEXTS: Tuttle, *Range Prediction Manual* (CONFIDENTIAL); selected publications. PREREQUISITE: OC 3616 concurrently.

OC 3700 OCEANOGRAPHIC INSTRUMENTATION AND OBSERVATIONS (3-0). Theory of design and operation of oceanographic instruments; recording of oceanographic observations, measurements, and samples on log sheets. TEXTS: H.O. 607, selected references. PREREQUISITE: OC 3220.

OC 3710 FIELD EXPERIENCE IN OCEANOGRAPHY (0-4). Laboratory course taught in conjunction with OC 3700. Use of standard oceanographic instruments in the conduct of a comprehensive oceanographic survey; processing and storage of data and samples; interpretation of results. TEXTS: H.O. 607; selected references. PREREQUISITE: OC 3700 concurrently.

#### Graduate Courses

OC 4211 WAVES AND TIDES (4-0). Theory of surface waves of small amplitude; theory of finite amplitude waves; wind-wave spectra; theory of the astronomical tides; tide analysis and prediction; tidal oscillations in ocean basins; tidal currents. TEXTS: Kinsman, *Wind Waves*; Defant, *Ebb and Flow*; Defant, *Physical Oceanography, Vol II*. PREREQUISITE: OC 4251 concurrently.

OC 4213 COASTAL OCEANOGRAPHY (4-1). Transformation of waves in shoal water; surf forecasting; storm tides; near-shore water circulation and littoral drift; characteristics of beaches and coasts. TEXTS: Weigel, *Oceanographical Engineering*; H.O. 234, Breakers and Surf. PREREQUISITES: OC 3601 and OC 3605.

OC 4251 DYNAMICAL OCEANOGRAPHY I (4-0). The equations of relative motion, incompressible flow, energy conservation, vorticity, turbulence and diffusion, and bound-

dary layer flow in the ocean. Special cases of flow in the sea, particularly geostrophic motion. TEXTS: Haltiner and Martin, *Dynamical and Physical Meteorology*; Stommel, *The Gulf Stream*; Fomin, *The Dynamical Method*. PREREQUISITES: OC 2110 and MA 3132.

OC 4252 DYNAMICAL OCEANOGRAPHY II (4-0). The wind-driven circulation and topographical influence on ocean currents; non-linear theories of the wind-driven circulation; the equation of state; convection cells; general treatment of thermal motions; theories of the thermocline and the deep thermohaline circulation. TEXTS: Defant, *Physical Oceanography*; Stommel, *The Gulf Stream*. PREREQUISITE: OC 4251.

OC 4253 DYNAMICAL OCEANOGRAPHY III (3-0). Laws of thermodynamics with applications to ideal gases, to the real atmosphere, and to sea water; thermohaline circulation; stability analysis. TEXTS: Haltiner and Martin, *Dynamical and Physical Meteorology*; Defant, *Physical Oceanography*. PREREQUISITE: OC 4252.

OC 4260 SOUND IN THE OCEAN (3-0). An introduction to the physics of underwater acoustics followed by a detailed discussion of the oceanographic factors affecting sound transmission in the ocean, including absorption, reflection from the surface and bottom, refraction, scattering, and ambient noise in the ocean; normal mode propagation; recent Navy developments. TEXTS: Selected references; Kinsler and Frey, *Fundamentals of Acoustics, 2nd ed.* PREREQUISITES: OC 3220, OC 3320, OC 3420, OC 3520.

OC 4340 MARINE GEOPHYSICS (3-0). Gravity, magnetism, seismicity, and other geophysical characteristics of the oceans and sea floor. Physical properties and composition of the sea floor. Structure of the earth's crust and upper mantle. Origin of the ocean basin and formation of major sea-floor features. TEXTS: Dobrin, *Geophysical Prospecting, 2nd ed.*; selected publications. PREREQUISITE: OC 3320.

OC 4421 MARINE ECOLOGY (1-4). The habits, classification, development, and adaptations of marine animals and plants with particular reference to the ecology of Monterey Bay. The relationships of physical, chemical, geological, and biological factors of the environment to marine organisms. Primarily laboratory investigations and field work dealing with the intertidal area, harbors, estuaries, and the near-shore pelagic and benthic environments of the associated organisms. TEXT: Selected publications. PREREQUISITE: OC 3420.

OC 4612 POLAR OCEANOGRAPHY (3-0). Marine geography of the Arctic; sea-ice observations, properties, formation, growth, deformation, and disintegration; sea-ice drift due to wind and currents. TEXT: Sea Ice Manual (unpublished). PREREQUISITE: OC 4211.

OC 4900 SEMINAR IN OCEANOGRAPHY (3-0). Students in the environmental sciences curricula conduct original research or summarize the literature in oceanography concerning a special topic, and during their last term present their findings in group discussions. Independently of this, the recent literature in various fields is surveyed, and important papers are presented by individual students.

## DEPARTMENT OF OPERATIONS ANALYSIS

JACK RAYMOND BORSTING, Professor of Operations Research, Chairman (1959)\*; B.A., Oregon State Univ., 1951; M.A., Univ. of Oregon, 1952; Ph.D., 1959.

ALVIN FRANCIS ANDRUS, Associate Professor of Operations Research (1963); B.A., Univ. of Florida, 1957; M.A., 1958.

DONALD R. BARR, Assistant Professor of Operations Research (1966); B.A., Whittier College, 1960; M.S., Colorado Univ., 1962; Ph.D., 1965.

EAMON BOYD BARRETT, Assistant Professor of Operations Research (1966); B.A., Univ. of Oregon, 1953; M.A., 1958; Ph.D., Stanford Univ., 1967.

RICHARD MAX BURTON, Assistant Professor of Operations Research (1967); B.S., Univ. of Illinois, 1961; M.B.A., 1963; D.B.A., 1967.

ARTHUR CAROL, Assistant Professor of Operations Research (1966); A.B., Cornell Univ., 1958; Ph.D., New York School for Social Research, 1966.

ROBERT NAEGLE FORREST, Associate Professor of Operations Research (1964); B.S., Univ. of Oregon, 1950; M.S., 1952; M.S., 1954; Ph.D., 1959.

HAROLD GREENBERG, Associate Professor of Operations Research (1967); B.A., Brooklyn College, 1949; M.S., New York Univ., 1958; Ph.D., 1964.

GILBERT THOREAU HOWARD, Assistant Professor of Operations Research (1967); B.S., Northwestern Univ., 1963; Ph.D., Johns Hopkins Univ., 1967.

CARL RUSSELL JONES, Associate Professor of Operations Research (1965); B.S., Carnegie Institute of Technology, 1956; M.B.A., Univ. of Southern California, 1963; Ph.D., Claremont Graduate School, 1965.

RONALD KOCHEMS, Assistant Professor (1965); B.S., Purdue Univ., 1961; M.S., 1962.

HAROLD JOSEPH LARSON, Associate Professor of Operations Research (1962); B.S., Iowa State Univ., 1956; M.S., 1957; Ph.D., 1960.

GLENN FRANK LINDSAY, Assistant Professor of Operations Research (1965); B.Sc., Oregon State Univ., 1960; M.Sc., The Ohio State Univ., 1962; Ph.D., 1966.

ALAN WAYNE McMASTERS, Assistant Professor of Operations Research (1965); B.S., Univ. of California, 1957; M.S., 1962; Ph.D., 1966.

PAUL ROBERT MILCH, Assistant Professor of Operations Research (1963); B.S., Brown Univ., 1958; Ph.D., Stanford Univ., 1966.

CLAIR ALTON PETERSON, Associate Professor of Operations Research (1962); B.B.A., Univ. of Minnesota, 1951; Ph.D., Massachusetts Institute of Technology, 1961.

STEPHEN MICHAEL POLLOCK, Assistant Professor of Operations Research (1965); B.E.P., Cornell Univ., 1958; M.S., Massachusetts Institute of Technology, 1960; Ph.D., 1964.

ROBERT RICHARD READ, Associate Professor of Operations Research (1961); B.S., Ohio State Univ., 1951; Ph.D., Univ. of California, 1957.

DAVID ALAN SCHRADY, Assistant Professor of Operations Research (1965); B.S.M.S., Case Institute of Technology, 1961; M.S., 1963; Ph.D., 1965.

REX HAWKINS SHUDDE, Associate Professor of Operations Research (1962); B.S., B.A., Univ. of California at Los Angeles, 1952; Ph.D., Univ. of California, 1956.

JOHN ALBERT TIEDEMAN, Visiting, Professor of Operations Research (1966); B.S., Union College, 1926; M.S., 1928; Ph.D., Univ. of Virginia, 1931.

GARY ALLEN TUCK, Assistant Professor of Operations Research (1966); B.A., Univ. of Oklahoma, 1955; M.S., 1964; Ph.D., 1965.

JOSEPH BRYCE TYSVER, Associate Professor of Operations Research (1966); B.A., Washington State Univ., 1942; M.A., 1948; Ph.D., Univ. of Michigan, 1957.

WALTER MAX WOODS, Associate Professor of Operations Research (1961); B.S., Kansas State Teachers College, 1951; M.S., Univ. of Oregon, 1957; Ph.D., Stanford Univ., 1961.

PETER W. ZEHNA, Professor of Operations Research (1961); B.A., Colorado State College, 1950; M.A., 1951; M.A., Univ. of Kansas, 1956; Ph.D., Stanford Univ., 1959.

HANS JACOB ZWEIG, Associate Professor of Operations Research (1965); B.A., Univ. of Rochester, 1949; M.A., Brown Univ., 1951; Ph.D., Stanford Univ., 1963.

\*The year of joining the Postgraduate School Faculty is indicated in parentheses.

## DEPARTMENT REQUIREMENTS FOR DEGREES IN OPERATIONS RESEARCH

Programs leading to degrees in Operations Research must be arranged in consultation with the Chairman, Department of Operations Analysis.

## BACHELOR OF SCIENCE IN OPERATIONS RESEARCH

1. The basic requirements for the degree of Bachelor of Science in Operations Research consists of a minimum of 60 upper division quarter hours at the Naval Postgraduate School and including at least:

- a. 36 quarter hours of Operations Research/Systems Analysis and Probability and Statistics.
- b. 12 quarter hours outside the Department of Operations Analysis.

2. The student must maintain a QPR of at least 1.2 in courses offered by the Department of Operations Analysis.



**MASTER OF SCIENCE IN OPERATIONS RESEARCH**

1. A candidate shall previously have satisfied the requirements for the degree of Bachelor of Science in Operations Research or the equivalent.

2. Completion of a minimum of 48 quarter hours of graduate level courses, including at most 8 quarter hours for a thesis.

a. At least 18 quarter hours of 4000 level Operations Research/Systems Analysis courses.

b. An elective sequence approved by the Department of Operations Analysis.

3. Submission of an acceptable thesis on a subject previously approved by the Department of Operations Analysis. This credit shall not count toward the requirement stated in 2 a.

**OPERATIONS ANALYSIS**

OA 0001 SEMINAR (0-2). Review of summer assignments, selection of thesis topics, special lectures. PREREQUISITE: None.

*Upper Division Courses*

OA 2201 ELEMENTS OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-0). An introductory course. Topics covered include, nature, origin, and contemporary status of operations analysis; problem formulations, measures of effectiveness, brief introduction to linear programming, game theory, and system reliability. PREREQUISITE: PS 2111 or equivalent.

OA 2601 INTRODUCTION TO OPERATIONS ANALYSIS (4-0). Development of the fundamental concepts of operations and systems analysis. History of operations analysis. Formulation of mathematical models. Determination of effectiveness as a product of measures of search, contact, attack, and kill probabilities. Lanchester's equations. The nature of proof and model building. PREREQUISITE: None.

OA 2602 WAR GAMING AND SIMULATION (3-2). Consideration of the problems inherent in the construction and use of manual and computer war games. Problems in the analysis of results of such games. Construction of digital simulation using FORTRAN and SIMSCRIPT. PREREQUISITE: None.

*Upper Division or Graduate Courses*

OA 3201 FUNDAMENTALS OF OPERATIONS ANALYSIS (4-0). An introduction to quality assurance elements including design reliability assessment, production assessment testing, environmental testing, system reliability demonstration. Introduction to hardware performance measures. Introduction to cost effectiveness analysis. Elements of probability and statistics developed as needed. PREREQUISITE: Differential and Integral Calculus.

OA 3202 METHODS OF OPERATIONS ANALYSIS/SYSTEMS ANALYSIS (4-0). Methodology of operations analysis/systems analysis. Statistical estimation, and hypo-

thesis testing. Life testing plans, point and interval estimates and reliability parameters. Elements of systems analysis pertaining to redundancy, maintainability, and spares. The role of systems analysis in solving military problems. PREREQUISITE: OA 3201 or equivalent.

OA 3203 SURVEY OF OPERATIONS ANALYSIS/SYSTEMS ANALYSIS (4-0). A survey of the military applications of operations analysis/systems analysis techniques of particular interest to the student. The applications usually covered are selected from decision, waiting lines resource allocation, replacement, cost-effectiveness, inventory theory, and search models. The techniques needed for these applications are developed as required and usually include topics in linear programming (including the simplex method), probability theory, nonlinear programming, statistics (including Bayesian and classical), dynamic programming and simulation. PREREQUISITE: PS 3112 or equivalent.

OA 3204 SYSTEMS ANALYSIS (4-0). The aim of this course is to present the nature, the aims, and limitations of analysis as it exists today and contributes to military problems. The common principles of cost/effectiveness analysis, design and formulation of the study, methods of solution, sensitivity analysis, pitfalls and limitations. Case studies from the field of interest of the class will be discussed. PREREQUISITE: PS 3112 or equivalent.

OA 3205 OPTIMIZATION TECHNIQUES (4-0). Problems in the analysis of complex systems, and in the solution of single-stage and multi-stage decision problems in management science. Constrained extrema, Lagrangian multipliers, gradient methods, search strategies, optimization properties of convex functions; linear, quadratic and dynamic programming. Capabilities and limitations of various computational techniques. Applications in areas such as optimal control, econometrics and resource allocation. PREREQUISITE: PS 3303 or equivalent.

OA 3211 OPERATIONS ANALYSIS FOR MANAGEMENT (4-0). Introduction to the philosophy and methodology of operations research. Survey of some of the more elementary techniques relating to decision making and optimization. PREREQUISITE: PS 3101.

OA 3212 OPERATIONS ANALYSIS FOR MANAGEMENT II (4-0). A continuation of OA 3211. Topics include: queueing, reliability, linear and dynamic programming, and gaming. PREREQUISITE: OA 3211.

OA 3213 INTRODUCTION TO LOGISTICS AND SUPPLY SYSTEMS (4-0). An introduction to logistic and supply management problems. Elements of inventory model building, allocation schemes, supply point locations, and correlation of specific logistic support activities. Emphasis on data source, collection, and reporting systems needed for management to operate supply systems economically. PREREQUISITE: OA 3212.

OA 3604 LINEAR PROGRAMMING (4-0). Theory of optimization of linear functions subject to linear constraints. The simplex algorithm, duality, dual simplex algorithm,



sensitivity analysis, transportation algorithm, parametric linear programming, matrix payoff games, and integer linear programming. PREREQUISITE: MA 2042.

OA 3605 METHODS OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-0). A first course designed to survey the methodology of operations research and systems analysis. Topics in this sequence include: dynamic programming, PERT and PERT/COST, queueing, reliability, maintenance, replacement, networks, stochastic models, and allocation of search. PREREQUISITE: OA 3604.

OA 3610 UTILITY THEORY AND RESOURCE ALLOCATION MODELS (4-0). The nature of individual preferences and their utility function representation in certain and risk environments. Introduction to utility functions (social welfare functions) for groups. The resource allocation problem of firms and economies interpreted as linear programming models. Introduction to nonlinear resource allocations models. PREREQUISITES: MN 3141, OA 3604.

OA 3611 SYSTEMS ANALYSIS I (4-0). Principles of systems analysis and their relationship to the planning, programming, and budgeting system (PPBS), and the traditional OR models. Analysis of effectiveness measures and models. Cost estimating and analysis. Overall structure of cost-effectiveness models and decision criteria. Risk and uncertainty problems. Current case studies and student design of studies. PREREQUISITES: OA 3604, OA 3610 (concurrently), PS 3303.

OA 3612 SYSTEMS ANALYSIS II (4-0). Continuation of Systems Analysis I. Detailed study of effectiveness models, cost models, and cost-effectiveness techniques. Major emphasis on individual and group projects. Student play of a military planning game, including a student designed PPBS with cost-effectiveness studies. PREREQUISITE: OA 3611.

OA 3620 INVENTORY I (4-0). A study of deterministic inventory models. Operating doctrines and their dependence upon costs. Constraints and optimization techniques. Periodic review models. PREREQUISITES: MA 2110, PS 3303 (may be taken concurrently).

OA 3621 INVENTORY II (4-0). A study of stochastic inventory models. Reorder point models with stochastic demands. Dynamic inventory models. Applications to logistics and Navy supply systems. PREREQUISITE: OA 3620.

OA 3653 SYSTEMS SIMULATION (4-0). Development of logical, numerical and statistical models of systems. The computer as an experimental tool. Basic elements such as entities, events, queues, routing, priorities, etc., and their interrelation. Sampling theory. The generation, termination, and flow of entities possessing prescribed attributes through storage and processing facilities. Balancing systems, sharing facilities, and using priorities to modify performance. Collection and evaluation of statistics on passage times, flow volumes, queue lengths, manpower and equipment utilization. Use of computer simulation languages, e.g., GPSS, SIMSCRIPT, DYNAMO, to simulate actual systems such as

a communication network or real-time, multi-processing computer system. PREREQUISITE: PS 3303 or equivalent.

OA 3655 METHODS FOR COMBAT DEVELOPMENT EXPERIMENTATION (4-0). Introduction to the intent, design, procedures, analysis, and reporting of field experiments. Rationale for combat experiments, criteria selection, statistical analysis, and interpretation of results. PREREQUISITES: OA 3604, PS 3303.

OA 3656 OPERATIONS RESEARCH PROBLEMS IN SPECIAL WARFARE (4-0). The applicability of operations research to unconventional warfare and counterinsurgency. Normative and descriptive models. Consideration of special problems with emphasis on problem formulation. PREREQUISITES: OA 3604, PS 3303.

OA 3657 HUMAN FACTORS IN SYSTEMS DESIGN (4-0). The human element in man-machine systems. Selected topics in human engineering and psychophysics with emphasis on their relation to military systems. PREREQUISITES: OA 3604, PS 3303.

OA 3664 THEORY OF PATTERN RECOGNITION (3-0). Survey of principles governing the design of pattern recognition and detection devices of both the adaptive and non-adaptive type. PREREQUISITE: PS 3303.

OA 3671 CYBERNETICS (3-0). This course deals with the problems of controlling very complex systems by feedback and "black boxes." Contributions to the theory of cybernetics from logic, biophysics, and other sources are developed. Applications are made to mechanical, social, and mental systems. PREREQUISITES: PS 3303, MA 2110, OA 3610.

OA 3672 DECISION CRITERIA (3-0). Survey and critique of the current literature dealing with decision criteria. Philosophy of values and allocation of effort. Applications to problems of human relations. PREREQUISITES: OA 3604, PS 3303.

OA 3704 STOCHASTIC MODELS I (4-0). Markov chains. Basic concepts, transition probabilities, and classification characteristics of Markov chains, random walks, and branching processes. Applications to basic systems models and queues. PREREQUISITE: PS 3303.

OA 3900 WORKSHOP IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Consent of instructor.

OA 3910 SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in operations research.

OA 3930 READING IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Consent of instructor.

OA 3940 SEMINAR IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Content of course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of instructor.

#### *Graduate Courses*

OA 4613 THEORY OF SYSTEMS ANALYSIS (4-0). Systems analysis (cost-effectiveness analysis) formulated as commensurable and incommensurable physical capital investment choice models. Emphasis on decision rules and the nature of opportunity costs with respect to scale and timing of investment. Interpretation of methods of risk modeling and solution computation. Theory of the second best; theory of the social discount rate. Introduction to models of planning and control emphasizing and decentralization of the decision-making problem. PREREQUISITES: OA 3612, OA 4631.

OA 4615 ECONOMETRICS (3-0). An introduction to the construction of testing of econometric models, analysis of economic time series, and the use of multivariate statistical analysis in the study of economic behavior. PREREQUISITES: PS 3303, OA 3604. Macroeconomic theory desirable.

OA 4622 SEMINAR IN SUPPLY SYSTEMS (4-0). A survey of supply systems, not only from an inventory point of view, but also as a critical area in logistics. Topics for discussion will be selected from the current literature and will be chosen according to students' interests. Periodically, experts in the supply field will provide guest lectures on current research areas. PREREQUISITES: OA 3621, OA 3704, or consent of instructor.

OA 4631 NONLINEAR AND DYNAMIC PROGRAMMING (4-0). Introduction to modern optimization techniques and multistage decision processes. Topics include: Kuhn-Tucker theory, quadratic programming, stochastic programming, chance-constrained programming, gradient and search methods, and dynamic programming. PREREQUISITES: OA 3604, MA 2110.

OA 4632 MATHEMATICAL PROGRAMMING (4-0). The bounded variable algorithm, decomposition principle, primal-dual algorithm. Special topics such as linear fractional programming, stochastic programming, chance-constrained linear programming, theory of degeneracy procedures, and the generalized transportation problem. Applications: PERT and PERT/COST, warehouse problem, caterer problem, assignment problems, overtime production, etc. PREREQUISITE: OA 3604.

OA 4633 NETWORK FLOWS AND GRAPHS (3-0). Survey of solution techniques for problems which can be formulated in terms of flow in networks. Elements of graph theory, max-flow min-cut theorem, shortest route, minimum cost flows, out-of-kilter algorithm, optimum flows with gains, and multi-commodity network flows. Application to transportation problems, critical path scheduling, production scheduling, and inventory problems. PREREQUISITE: OA 3604.

OA 4634 GAMES OF STRATEGY (4-0). Continuous games on the unit square,  $n$ -person games, non-zero sum games, and introduction to differential games. Applications and case studies. PREREQUISITES: OA 3604, PS 3303, or equivalent.

OA 4642 ADVANCED WAR GAMING (3-2). Development of event-store and time-step digital war games. Advanced Monte Carlo techniques. Simulation laboratory concepts and use of remote terminal displays. PREREQUISITES: OA 2602, PS 3303, or equivalent.

OA 4651 SEARCH THEORY AND DETECTION (4-0). Search and detection as stochastic processes. Characterization of detection devices, use and interpretation of sweep widths, lateral range curves, true range curves. Measures of effectiveness of search-detection systems. Allocation of search effort, sequential search. Introduction to the statistical theory of signal detection. Models of surveillance fields, barriers, tracking, and trailing. PREREQUISITE: PS 3303 or equivalent.

OA 4652 AIR WARFARE (3-0). Analyses of fleet air defense exercises. Changes in tactics and force disposition arising from the introduction of nuclear weapons and missiles. Active and passive air defense. Relationship of air defense to strike capability and ASW. Operations analysis of detection and communication systems. Emphasizes current radar and ECM problems. PREREQUISITE: OA 4651.

OA 4662 SYSTEMS RELIABILITY AND LIFE TESTING (4-0). Reliability functions and their point and interval estimates under various sampling plans. Standard and accelerated life testing plans. Analysis of serial, parallel, and mixed systems. Analysis of reliability apportionment and inherent design reliability. Reliability growth models and methods for updating reliability estimates. Properties of functions with monotone failure rate. PREREQUISITE: OA 4705 or equivalent.

OA 4673 UTILITY THEORY (3-0). General concept of utility and its measurement. Survey and critique of the current literature dealing with the concept and measurement of utility. Applications to problems of human relations. PREREQUISITE: OA 3610.

OA 4705 STOCHASTIC MODELS II (4-0). Poisson processes. Renewal theory and semi-Markov processes. Stochastic models of complex military systems and applications in economics, communications, and inventory models. Maintenance policies. PREREQUISITE: OA 3704.

OA 4900 WORKSHOP IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Consent of instructor.

OA 4910 SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in operations research.

OA 4930 READING IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Consent of instructor.

OA 4940 SEMINAR IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Content of course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of instructor.

## PROBABILITY AND STATISTICS

### *Upper Division Courses*

PS 2301 PROBABILITY (4-0). Axiomatic development of probability and its use in model building. Random variables and their probability distributions. Moments and other characteristics of probability laws and their importance in formulating and solving operations analysis problems. Jointly distributed random variables and their use in defining behavior of complex systems. PREREQUISITE: A previous course in differential and integral calculus.

### *Upper Division or Graduate Courses*

PS 3302 PROBABILITY AND STATISTICS (4-1). Independence and conditional distributions. Stochastic inequalities, approximations, and limit properties, and their use in operations analysis/systems analysis. Derived distributions of functions of random variables. Random sampling and distribution of sampling statistics with application to model building and Bayesian techniques. PREREQUISITE: PS 2301.

PS 3303 STATISTICS (4-1). Confidence interval estimation and hypothesis testing. Regression and correlation analysis. Elements of the analysis of variance. Nonparametric inference. Applications to reliability, quality assurance, and operations analysis problems. PREREQUISITE: PS 3302.

PS 3510 SELECTED TOPICS IN PROBABILITY AND STATISTICS (2-0 to 5-0). Topics will be selected by instructor to fit the needs and background of the students. The topics may include advanced probability, sampling inspection, quality assurance, nonparametric methods, and sequential analysis. The course may be repeated for credit if the topic changes. PREREQUISITE: PS 3303 or consent of the instructor.

### *Graduate Courses*

PS 4306 APPLIED STATISTICS (4-0). Multivariate analysis with applications. Multiple comparisons. Bayesian and classical classification models. Outliers. Use of digital computer in multivariate problems. PREREQUISITE: PS 3303.

PS 4321 DESIGN OF EXPERIMENTS (3-1). Theory of the general linear hypotheses. Analysis of variance. Planning of experiments. Randomized block and Latin squares. Simple factorial experiments. PREREQUISITE: PS 3303 or consent of instructor.

PS 4322 SAMPLE INSPECTION AND QUALITY ASSURANCE (3-1). Attribute and variables sampling plans. MIL. STD. sampling plans with modifications. Multi-level continuous sampling plans and sequential sampling plans. Structure of quality assurance programs and analysis of selected quality assurance problems. PREREQUISITE: PS 3303.

PS 4323 DECISION THEORY (3-0). Basic concepts. Bayes, admissible, minimax, and regret strategies. Principles of choice. Relation of statistical decision functions to the theory of games. Applications in the planning of operational evaluations trials. PREREQUISITE: PS 3303.

PS 4431 ADVANCED PROBABILITY (3-0). Convergence almost surely, in probability and in quadratic mean. Distribution function and characteristic functions. Infinitely divisible laws. Strong and weak laws of large numbers. Classical central limit problems, modern central limit problems. PREREQUISITE: MA 4635 and consent of instructor.

PS 4432 STOCHASTIC PROCESSES (3-0). Orthogonal representation of stochastic processes. Stationary time series; harmonic analysis of the auto-correlation function. Ergodic properties. Applications. PREREQUISITE: OA 4705.

PS 4510 SELECTED TOPICS IN PROBABILITY AND STATISTICS (2-0 to 5-0). Topics will be selected by instructor to fit the needs and background of the students. The topics may include advanced probability, sampling inspection, quality assurance, nonparametric methods, and sequential analysis. The course may be repeated for credit if the topic changes. PREREQUISITE: PS 3303 or consent of the instructor.



## DEPARTMENT OF PHYSICS

OTTO HEINZ, Professor of Physics, Chairman (1962); B.A., Univ. of California at Berkeley, 1948; Ph.D., 1954.

ROBERT LOUIS ARMSTEAD, Assistant Professor of Physics (1964); B.S., Univ. of Rochester, 1958; Ph.D., Univ. of California at Berkeley, 1965.

FRANZ AUGUST BUMILLER, Professor of Physics (1962); M.S., Univ. of Zurich, 1951; Ph.D., 1955.

FRED RAMON BUSKIRK, Associate Professor of Physics (1960); B.S., Western Reserve Univ., 1951; Ph.D., Case Institute of Technology, 1958.

ALFRED WILLIAM MADISON COOPER, Associate Professor of Physics (1957); B.A., Univ. of Dublin, 1955; M.A., 1959; Ph.D., The Queen's University of Belfast, 1961.

JOHN NIESSINK COOPER, Professor of Physics (1956); B.A., Kalamazoo College, 1935; Ph.D., Cornell Univ., 1940.

ALAN BERCHARD COPPENS, Assistant Professor of Physics (1964); B.Eng.Phys., Cornell Univ., 1959; M.S., Brown Univ., 1962; Ph.D., 1965.

EUGENE CASSON CRITTENDEN, JR., Professor of Physics (1953); B.A., Cornell Univ., 1934; Ph.D., 1938.

PETER PIERCE CROOKER, Instructor in Physics (1960); B.S., Oregon State College, 1959.

WILLIAM PEYTON CUNNINGHAM, Professor of Physics (1946); B.S., Yale Univ., 1928; Ph.D., 1932.

HARVEY ARNOLD DAHL, Assistant Professor of Physics (1964); B.S., Stanford Univ., 1951; Ph.D., 1963.

JOHN NORVELL DYER, Associate Professor of Physics (1961); B.A., Univ. of California at Berkeley, 1956; Ph.D., 1960.

AUSTIN ROGERS FREY, Professor of Physics (1946); B.S., Harvard Univ., 1920; M.S., 1924; Ph.D., 1929.

HARRY ELIAS HANDLER, Professor of Physics (1958); B.A., Univ. of California at Los Angeles, 1949; M.A., 1951; Ph.D., 1955.

DON EDWARD HARRISON, JR., Associate Professor of Physics (1961); B.S., College of William and Mary, 1949; M.S., Yale Univ., 1950; Ph.D., 1953.

WILLIAM LEWIS JOHNSON, Lieutenant (junior grade), U.S. Naval Reserve; Instructor in Physics (1963); B.S., Univ. of Southern Mississippi, 1962.

SYDNEY HOBART KALMBACH, Professor of Physics (1947); B.S., Marquette Univ., 1934; M.S., 1937.

RAYMOND LEROY KELLY, Associate Professor of Physics (1960); B.A., Univ. of Wichita, 1947; M.S., Univ. of Wisconsin, 1949; Ph.D., 1951.

LAWRENCE EDWARD KINSLER, Professor of Physics (1946); B.S., California Institute of Technology, 1931; Ph.D., 1934.

HERMAN MEDWIN, Professor of Physics (1955); B.S., Worcester Polytechnic Institute, 1941; M.S., Univ. of California at Los Angeles, 1948; Ph.D., 1953.

EDMUND ALEXANDER MILNE, Associate Professor of Physics (1954); B.A., Oregon State College, 1949; M.S., California Institute of Technology, 1950; Ph.D., 1953.

JOHN ROBERT NEIGHBOURS, Professor of Physics (1959); B.S., Case Institute of Technology, 1949; M.S., 1951; Ph.D., 1953.

NORMAN LEE OLESON, Professor of Physics (1948); B.S., Univ. of Michigan, 1935; M.S., 1937; Ph.D., 1940.

LEONARD OLIVER OLSEN, Professor of Physics (1960); B.A., Iowa State Teachers College, 1932; M.S., State Univ. of Iowa, 1934; Ph.D., 1937.

WILLIAM REESE, Associate Professor of Physics (1963); B.A., Reed College, 1958; M.S., Univ. of Illinois, 1960; Ph.D., 1962.

JOHN DEWITT RIGGIN, Professor of Physics (1946); B.S., Univ. of Mississippi, 1934; M.S., 1936.

GEORGE WAYNE RODEBACK, Associate Professor of Physics (1960); B.S., Univ. of Idaho, 1943; M.S., Univ. of Illinois, 1947; Ph.D., 1951.

JAMES VINCENT SANDERS, Assistant Professor of Physics (1961); B.S., Kent State Univ., 1954; Ph.D., Cornell Univ., 1961.

GORDON EVERETT SCHACHER, Associate Professor of Physics (1964); A.B., Reed College, 1956; Ph.D., Rutgers, 1961.

RONALD WAYNE STAAB, Lieutenant (junior grade); Naval Reserve; Instructor in Physics (1965); B.S., Columbia Univ., 1964; M.S., 1965.

OSCAR BRYAN WILSON, JR., Professor of Physics (1957); B.S., Univ. of Texas, 1944; M.A., Univ. of California at Los Angeles, 1948; Ph.D., 1951.

KARLHEINZ EDGAR WOEHLE, Associate Professor of Physics (1963); B.S., Univ. of Bonn, 1953; M.S., Technical Univ., Aachen, 1955; Ph.D., Univ. of Munich, 1962.

WILLIAM BARDWELL ZELNY, Associate Professor of Physics (1962); B.S., Univ. of Maryland, 1956; M.S., Syracuse Univ., 1958; Ph.D., 1960.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES  
IN PHYSICS

## BACHELOR OF SCIENCE IN PHYSICS

1. A major in physics must include a minimum of 45 quarter hours in physics, including required courses and electives, a minimum of 24 quarter hours in mathematics, and the equivalent of a course in general chemistry. In addition a minimum of 17 quarter hours of elective credits must be chosen from the natural sciences or engineering,

other than physics or mathematics. Ninety quarter hours must be clearly of upper division level.

2. The following specific requirements must be met: (courses marked with an asterisk must include a laboratory).

<i>Subject</i>	<i>Approximate Quarter Hrs.</i>
General Physics*	13
Analytical Mechanics	7
Electricity and Magnetism	6
Modern Physics*	10
	<hr/> 36

The math courses shall include differential equations and vector analysis.

3. The student must maintain grade point averages of at least 1.2 in both physics and mathematics.

### MASTER OF SCIENCE IN PHYSICS

1. Each student's program of study must have a minimum of 30 quarter hours of physics courses (not including thesis) distributed between courses in the 3000 and 4000 series; of this 30 hours, a minimum of 10 hours must be from the 4000 series. In lieu of the preceding requirement, students who are qualified to pursue graduate courses in physics when they arrive at the Postgraduate School may complete a minimum of 20 hours entirely of 4000 level physics courses. In addition, all students must engage in research in at least 3 quarters and present an acceptable thesis.

2. In addition to the courses normally leading to a B.S. in physics, the following specific course requirements must be successfully completed for a student to earn the degree of M.S. in physics:

- Thermodynamics and Statistical Mechanics. The student must take a two-quarter sequence or present equivalent preparation in this area.
- A course in Advanced Mechanics or Quantum Mechanics.
- A course in Electromagnetism at the 4000 level.
- An advanced course in Modern Physics.
- Specialization, to include at least two advanced courses, in one of the following areas:

- |                     |                         |
|---------------------|-------------------------|
| (1) Acoustics       | (5) Solid State Physics |
| (2) Atomic Physics  | (6) Underwater Physics  |
| (3) Nuclear Physics | (7) Other, subject to   |
| (4) Plasma Physics  | Department approval     |

### PHYSICS

PH 0499 ACOUSTICS COLLOQUIUM (0-1). Reports on current research and study of recent research literature in conjunction with the student thesis. PREREQUISITE: PH 3452 or equivalent.

PH 0999 PHYSICS COLLOQUIUM (0-1). Discussion of topics of current interest in the field of physics and student thesis reports.

### Lower Division Courses

PH 1005, PH 1006, and PH 1007 comprise a series of courses intended for students with limited backgrounds in mathematics.

PH 1005 ELEMENTARY PHYSICS I (3-2). Mechanics, Heat, and Sound. Lectures, problem sessions, and laboratory. Physical quantities and the concepts of motion, force, momentum, and energy. The mechanics of gases, heat transfer, and thermodynamics. Simple harmonic motion and propagation of sound. TEXT: Sears and Zemansky, *College Physics*, or equivalent.

PH 1006 ELEMENTARY PHYSICS II (3-2). Electricity and Magnetism. Electrostatics, electric current, and magnetism. Lectures, problem sessions, and laboratory. TEXT: Sears and Zemansky, *College Physics*, or equivalent. PREREQUISITE: PH 1005.

PH 1007 ELEMENTARY PHYSICS III (4-2). Optics and Modern Physics. Lectures, problem sessions and laboratory dealing with geometrical optics, mirrors and lenses. Atomic structure, optical spectra, radioactivity and nuclear structure. TEXT: Sears and Zemansky, *College Physics*, or equivalent. PREREQUISITES: PH 1005 and PH 1006.

PH 1011, PH 1012, and PH 2017 comprise a series of courses intended primarily for Engineering Science students with a prior knowledge of calculus.

PH 1011 BASIC PHYSICS I (4-0). Mechanics, Heat, and Sound. Review of Newtonian Mechanics. Conservation laws. Rotational motion. Thermal properties of gases, liquids and solids. Laws of Thermodynamics. Wave motion and propagation of sound. TEXT: Resnick-Halliday, *Physics, Part I*. PREREQUISITES: Courses in College Physics and College Mathematics through calculus.

PH 1012 BASIC PHYSICS II (4-0). Electricity and Magnetism. Electrostatics stressing Gauss's Law and the theory of electric fields and potentials. Alternating current. Electromagnetism. TEXT: Halliday-Resnick, *Physics, Part II*. PREREQUISITE: PH 1011.

PH 1015, PH 1016, and PH 2017 comprise a series of courses intended primarily for BS students, and provides a knowledge of the principles of physics and a scientific background for the study of engineering.

PH 1015 BASIC PHYSICS I (4-3). Mechanics, Heat, and Sound. Lectures, problem sessions, and laboratory. Concepts of force, motion, energy, momentum, thermal properties of gases, liquids, and solids, and wave motion. TEXT: Halliday-Resnick, *Physics, Part I*. PREREQUISITE: One term of calculus.

PH 1016 BASIC PHYSICS II (4-3). Electricity and Magnetism. Lectures, problem sessions, and laboratory. Electrostatics, electromagnetism, and electrochemistry. Direct and alternating currents. TEXT: Halliday-Resnick, *Physics, Part II*. PREREQUISITES: PH 1015.

PH 1041 REVIEW OF MECHANICS AND THERMODYNAMICS (4-0). First quarter of a sequence of fundamental physics for students in Electrical Engineering and Electronics. The sequence includes PH 1041, PH 2241, PH 3641, and PH 3741. The first course subject matter includes: kinematics, particle dynamics, energy, momentum, rotational motion, orbital motion, oscillations; temperature, entropy, first and second law of thermodynamics. TEXTS: Resnick and Halliday, *Physics for Students of Science and Engineering, Vol. I*; Christy and Pytte, *The Structure of Matter*.

PH 1051 REVIEW OF MECHANICS, THERMODYNAMICS, AND OPTICS (4-0). A review of the basic concepts of mechanics, thermodynamics, and optics, including: statics, motion in one dimension and in a plane, particle dynamics, energy, momentum, rotational dynamics, temperature, laws of thermodynamics, kinetic theory of gases, and geometrical optics. TEXT: Resnick-Halliday, *Physics, Parts I and II*. PREREQUISITES: Previous courses in general physics and calculus.

#### Upper Division Courses

PH 2017 BASIC PHYSICS III (4-2). Optics and Modern Physics. PH 2017 is the third course for both the PH 1011, PH 1012, and the PH 1015, PH 1016 series of Basic Physics. Lectures, problem sessions, and laboratory. Geometrical optics, mirrors and lenses. Interference and diffraction. Special relativity, quantum effects of waves and particles, structure of the hydrogen atom, nuclear structure, and nuclear reactions. TEXTS: Halliday-Resnick, *Physics, Part II*, and Weidner and Sells, *Elementary Modern Physics*. PREREQUISITES: PH 1011 and PH 1012 or PH 1015 and PH 1016.

PH 2121 PARTICLE DYNAMICS (4-0). Review of Newton's Laws of motion, work and energy, conservation laws. Central forces, moving reference systems. The motion of a particle in electromagnetic fields. TEXT: Resnick and Halliday, *Physics for Students of Science and Engineering, Parts I and II*.

PH 2151 MECHANICS I (4-0). Particle dynamics including oscillatory motion and central force motion. Motion of a system of particles. TEXT: Symon, *Mechanics, 2nd ed.* PREREQUISITES: PH 1051, Calculus, Vector Algebra and Ordinary Differential Equations (the latter may be taken concurrently).

PH 2221 WAVE PHENOMENA: (3-2). Wave phenomena and wave propagation, refraction, reflection, interference and diffraction, polarization. Thermal radiation. The electromagnetic nature of light and Maxwell's equations. TEXTS: Sears, *Optics*; Jenkins and White, *Fundamentals of Optics*. PREREQUISITE: PH 2121.

PH 2241 WAVES AND PARTICLES (4-0). Second quarter of a sequence of fundamental physics for students in Electrical Engineering and Electronics. Wave propagation, interference, diffraction, polarization. Electromagnetic waves. Photoelectric and Compton effects. Wave particle dualism. Black body radiation, spectra. TEXTS: Christy and Pytte, *The Structure of Matter*, Halliday and Resnick, *Physics for*

*Students of Science and Engineering, Vol. II*. PREREQUISITE: PH 1041 or PH 2151.

PH 2251 WAVES AND PARTICLES (4-2). A course designed to provide the background and fundamental ideas in modern physics which are utilized in atomic, molecular, solid state, and nuclear physics. Wave properties; propagation, interference, diffraction, polarization. Electromagnetic waves. The special theory of relativity. Photoelectric and Compton effects. Wave-particle dualism; de Broglie hypothesis; electron diffraction; wave packets. Continuous and line spectra; black-body radiation; hydrogen atom spectrum. TEXTS: Eisberg, *Fundamentals of Modern Physics*; Instructor's Notes. PREREQUISITES: PH 2151, MA 2161.

PH 2351 ELECTROMAGNETISM I (3-0). Electrostatics: Coulomb's law, electric field and potential dielectrics. Magnetostatics: magnetic fields due to currents and charges. Magnetic induction. Magnetic materials. Maxwell's wave equation. TEXT: Corson and Lorrain, *Introduction to Electromagnetic Fields and Waves*. PREREQUISITES: MA 2161, PH 1051.

PH 2400 SURVEY OF UNDERWATER SOUND AND ITS APPLICATIONS (3-0). This course is designed to acquaint the student with the physical properties of underwater sound, its environment and the related laws which pertain to its detection, especially in naval applications. The noise environment, sonar equation, range prediction, and passive and active detection mechanisms are some of the topics covered. TEXT: NDRC Technical Summary, *Principles of Underwater Sound*. PREREQUISITE: Calculus and Analytic Geometry I, or its equivalent.

PH 2551 THERMODYNAMICS (3-0). (may be taught as CH 2401) Fundamental theory of thermodynamics and applications to physical systems. First and second laws of thermodynamics; entropy; thermodynamic potentials; applications to gases, liquids, radiation, and magnetic materials; equilibrium. TEXT: Vanderslice, Schamp, and Mason, *Thermodynamics*. PREREQUISITES: PH 1051 and Calculus of Several Variables.

PH 2810 SURVEY OF NUCLEAR PHYSICS (4-0). A course designed to introduce the student to the ideas of nuclear physics, with emphasis on neutron physics and reactors. Atomic nature of matter; wave-particle duality: the nuclear atom. Basic nuclear properties; reactions, neutrons and fission. Reactors. TEXTS: Weidner and Sells, *Elementary Modern Physics*; Murray, *Introduction to Nuclear Engineering*.

#### Upper Division or Graduate Courses

PH 3152 MECHANICS II (4-0). Motion of a system of particles continued. Rotation of a rigid body. Moving coordinate systems. Some mechanics of continuous media. Generalized coordinates. Lagrange equations. TEXT: Symon, *Mechanics, 2nd ed.* PREREQUISITE: PH 2151.

PH 3280 PHYSICAL OPTICS (4-2). Wave phenomena and wave propagation, superposition principle and interference, dispersion, polarization, Stokes vector representa-



tion, Kirchoff integral. TEXT: Stone, *Radiation and Optics*. PREREQUISITE: Consent of Instructor.

PH 3352 ELECTROMAGNETISM II (3-0). Electromagnetic Waves: Wave equations, plane wave solutions, energy and momentum in electromagnetic waves. Plane waves in dielectrics and refraction, waves in conductors and ionized media, guided waves. TEXT: Corson and Lorrain, *Introduction to Electromagnetic Fields and Waves*. PREREQUISITE: PH 2351.

PH 3421 UNDERWATER ACOUSTICS (4-2). An analytical survey of acoustics with an emphasis on sound propagation in the ocean. Simple harmonic oscillations, the wave equation is an ideal fluid, simple harmonic solutions for plane and spherical waves, radiation of sound, propagation effects due to boundaries, inhomogeneities, and absorbing processes, development of the basic equations for sonar, transducers for underwater sound. Laboratory experiments on underwater acoustics, spectrum analysis and transducers. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics*, 2nd ed.; NDRC Summary Reports, *Principles of Underwater Sound and Physics of Sound in the Sea*. PREREQUISITES: PH 2151 or PH 2121.

PH 3451 FUNDAMENTAL ACOUSTICS (4-0). Mechanics of free, forced, and damped simple vibratory systems. Mechanical impedance. Development of, and solutions to, the acoustic wave equations in extended media. Propagation of plane waves in fluids and between media. Specific acoustic impedance. Spherical waves and simple sources. The acoustical behavior of the piston source. Radiation impedance. Steady state response of acoustic waveguides. Group and phase velocities. Normal Modes. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics*; Instructor's Notes. PREREQUISITES: PH 2151 and MA 2161.

PH 3452 UNDERWATER ACOUSTICS (4-2). Electro-mechanical coupling and interrelation of electrical, mechanical, and radiation impedances. Spatial and temporal absorption for classical and relaxing media, dispersion. Transmission of sound in the ocean, method of images, normal modes, refraction, ray diagrams. Scattering, reverberation, ambient and radiated noise, the sonar equations, active and passive systems. Laboratory experiments on selected concepts. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics*; Instructor's Notes. PREREQUISITE: PH 3451.

PH 3461 EXPLOSIVE SHOCK WAVES (4-0). Generation and propagation of explosive shock waves in air and water including Rankine-Hugoniot equations, scaling laws, reflection and refraction phenomena, and experimental data. Shock loads on ships and blast loads on structures. Damage mechanism and principles of protection against damage. TEXTS: Instructor's Notes; Cole, *Underwater Explosives*; Kinney, *Shocks in Air*. PREREQUISITES: PH 3152, PH 2551 or CH 2401.

PH 3463 SPECIAL TOPICS IN UNDERWATER ACOUSTICS (3-2). A terminal course following PH 3452 for students in a two-year program. Topics may include additional material in underwater acoustics, transducer theory, nonlinear phenomena in acoustics, explosive waves in

water, noise and vibration control. Laboratory experiments on related material. TEXT: Instructor's Notes. PREREQUISITE: PH 3452 or equivalent.

PH 3561 INTRODUCTORY STATISTICAL PHYSICS (4-0). Distribution functions, kinetic theory, transport processes, introduction to classical and quantum distributions. Applications to gases, solids, and radiation. TEXT: Andrews, *Equilibrium Statistical Mechanics*. PREREQUISITES: PH 3152, PH 2551 or CH 2401, PH 3651.

PH 3641 ATOMIC PHYSICS (4-2). Third quarter in the sequence of fundamental physics for students in Electrical Engineering and Electronics. Kinetic theory of gases, Boltzmann function, statistical distribution, Bohr model, Schrodinger's equation, free and bound particles, emission and absorption of radiation, the one electron atom, periodic table, many electron atoms, electron spin, X rays, vibration rotation spectra for molecules. TEXTS: Sproull, *Modern Physics*, 2nd ed.; Weidner and Sells, *Elementary Modern Physics*. PREREQUISITES: PH 2241 or PH 2251.

PH 3651 ATOMIC PHYSICS (4-2). Properties of the electron, the nuclear atom, the Bohr theory of the hydrogen atom, atomic energy levels, the Schrodinger Equation and properties of its solutions, application of the Schrodinger Equation to the square potential well and to the hydrogen atom, angular momentum operators, electron spin, identical particles, the Pauli Principle, multielectron atoms, the Periodic Table, the vector model of the atom and complex spectra, the Zeeman effect, Einstein coefficients and stimulated emission of radiation. TEXT: Eisberg, *Fundamentals of Modern Physics*. PREREQUISITES: PH 2251 and MA 2161.

PH 3652 ELEMENTS OF MOLECULAR, SOLID STATE, AND NUCLEAR PHYSICS (4-2). X-ray spectra, Bragg Law. Molecular bonds, excited states of molecules, molecular spectra. Bonding in crystals. Conduction in solids, band theory. Semiconductors. Fundamentals of nuclear physics, radioactivity and the decay law. Interactions of charged particles and photons with matter. TEXTS: Sproull, *Modern Physics*; Enge, *Introduction to Nuclear Physics*; Instructor's Notes. PREREQUISITE: PH 3651.

PH 3687 ELECTRICAL DISCHARGES IN GASES (3-0). A course covering the fundamental processes occurring in electrical discharges in gases. Emission of electrons from surfaces, excitation ionization, recombination, deexcitation of atoms and molecules. Mobility and diffusion, electrical breakdown in gases, glow and arc discharges, sheaths, experimental methods. TEXTS: McDaniel, *Collision Phenomena in Gases*; Von Engel, *Ionized Gases*; Francis, *Ionization Phenomena in Gases*. PREREQUISITES: PH 3641 or PH 3651.

PH 3741 ELECTRONIC PROPERTIES OF METALS AND SEMI-CONDUCTORS (4-2). Fourth quarter in the sequence of fundamental physics for students in Electrical Engineering and Electronics. Crystals and lattice properties, X-ray diffraction, free-electron theory, electrical conductivity, band theory, Brillouin zones, effective mass, holes, intrinsic and impurity semi-conductors, diodes, transistors, thermo-

electric effects, magnetic properties. TEXTS: Kittel, *Introduction to Solid State Physics*, 2nd ed.; Azaroff and Brophy, *Electronic Processes in Materials*. PREREQUISITES: PH 3641 or PH 3651.

PH 3921 CONCEPTUAL MODELS OF MODERN PHYSICS (4-0). A review of recent developments in physics selected to illustrate the principles of model-building and the general methodology of science. The topics selected include: special relativity, wave particle duality, nuclear reactions, and fundamental particles. TEXTS: Weidner and Sells, *Elementary Modern Physics*; Beiser, *Concepts of Modern Physics*. PREREQUISITE: PH 2221.

PH 3951 INTRODUCTION TO QUANTUM MECHANICS (3-0). The general principles of quantum mechanics. Schrodinger equation. Harmonic oscillator. Angular momentum, many particle systems, electron spin, the Pauli exclusion principle. Time independent and time dependent perturbation, and the semi-classical theory of radiation applied to atomic transitions. TEXT: Sherwin, *Introduction to Quantum Mechanics*. PREREQUISITES: PH 2351, MA 2161, PH 3651.

#### Graduate Courses

PH 4161 FLUID MECHANICS I (3-0). Fundamental concepts of continuum mechanics. Fluid mechanical models. Euler equation and solution of potential flow problems. Navier-Stokes equation. TEXTS: Instructor's Notes; Li and Lam, *Principles of Fluid Mechanics*. PREREQUISITES: PH 3152, MA 2161.

PH 4162 FLUID MECHANICS II (3-0). Laminar boundary layer, hydrodynamic stability, turbulence, and hydrodynamic noise. Fluid dynamic discontinuities, shock waves, and the method of characteristics. TEXTS: Schlichting, *Boundary Layer Theory*; Instructor's Notes. PREREQUISITE: PH 4161.

PH 4171 ADVANCED MECHANICS (4-0). Hamilton's principle. The equations of motion in Lagrangian and Hamiltonian form. Rigid body motion. Canonical transformation, Poisson brackets, Hamilton-Jacobi theory. Small oscillations. Classical perturbation theory. TEXT: Goldstein, *Classical Mechanics*. PREREQUISITES: PH 3152, PH 3352.

PH 4353 ELECTROMAGNETISM III (3-0). Classical radiation theory: Scalar and vector potentials, radiation from a dipole, classical theory of Bremsstrahlung, Thompson scattering, field due to fast electron. Selected topics: Relativity, scattering from a random medium, Rayleigh scattering. TEXT: Marion, *Classical Electromagnetic Radiation*. PREREQUISITE: PH 3352.

PH 4371 CLASSICAL ELECTRODYNAMICS (3-0). Tensors in special relativity. Classical relativistic electromagnetic field theory. The Lienard-Wiechert potentials. Lorentz electron theory. TEXTS: Landau and Lifshitz, *Classical Theory of Fields*; Barut, *Electrodynamics and Classical Theory of Fields and Particles*. PREREQUISITES: PH 4353, PH 4171, and familiarity with the special theory of relativity.

PH 4453 PROPAGATION OF WAVES IN FLUIDS (4-0). Advanced treatment of wave propagation including: The Eikonal Equation and necessary conditions for ray acoustics. Scattering of plane waves from targets of simple geometry. Radiation from simple sources in shallow-water channels. Propagation of transients in waveguides. Finite-amplitude waves in non-dissipative and absorptive fluids. TEXTS: Lindsay, *Mechanical Radiation*; Officer, *Introduction to the Theory of Sound Transmission*; Instructor's Notes. PREREQUISITE: PH 3452.

PH 4454 TRANSDUCER THEORY AND DESIGN (3-3). A theoretical treatment of the fundamental phenomena basic to the design of piezoelectric and magnetostrictive transducer elements and arrays of elements with the emphasis placed on underwater applications. Laboratory experiments on properties of piezoelectric materials, characteristics of various transducer types and measurement techniques. TEXTS: Mason, *Physical Acoustics, Vol. I, Part A*; Heuter and Bolt, *Sonics*. PREREQUISITE: PH 3452 or equivalent.

PH 4455 ADVANCED ACOUSTICS LABORATORY (0-3). Advanced laboratory projects in acoustics. PREREQUISITE: PH 3452 or equivalent.

PH 4456 SEMINAR IN APPLICATIONS OF UNDERWATER SOUND (3-0). A study of current literature on applications of acoustics to problems of naval interest. PREREQUISITE: PH 4453 or consent of the Instructor.

PH 4571 STATISTICAL PHYSICS I (3-0). Kinetic theory and the Boltzmann theorem, configuration and phase space, the Liouville theorem, ensemble theory, microcanonical, canonical, and grand canonical ensembles, quantum statistics. TEXT: Huang, *Statistical Mechanics*. PREREQUISITES: PH 3152, PH 3651, PH 2551.

PH 4572 STATISTICAL PHYSICS II (3-0). A continuation of PH 4571 with applications to molecules, Bose-Einstein gases, Fermi-Dirac liquids, and superconductivity. TEXT: Huang, *Statistical Mechanics*. PREREQUISITE: PH 4571.

PH 4661 PLASMA PHYSICS I (3-0). Introduction to physical and mathematical concepts fundamental to various branches of plasma physics, such as ionospheric communications, ion propulsion, plasma amplifiers and controlled fusion. Topics covered are collision phenomena, including surface effects, the Boltzmann equation, breakdown of a gas, diffusion both in presence and absence of space charge. The general hydrodynamic macroscopic equation is derived and from this the momentum transport and energy transport equations are obtained. The hydromagnetic equations for the two particle plasma are considered. TEXTS: Rose and Clark, *Plasma and Controlled Fusion*; Uman, *Introduction to Plasma Physics*; Glasstone and Loveberg, *Controlled Thermonuclear Reactions*. PREREQUISITES: PH 4371, PH 3561, PH 3651 or the equivalent.

PH 4662 PLASMA PHYSICS II (3-0). A continuation of Plasma Physics I. Application of hydromagnetic equations to study of macroscopic motions of a plasma, including conductivity of a magnetized Lorentzian gas. Simple shocks.



Effect of coulomb interactions, including discussion of relaxation times and runaway electrons. Study of small amplitude waves occurring in a plasma. Types of radiation from plasmas, including bremsstrahlung and cyclotron radiation. Plasma instabilities. TEXTS: Rose and Clark, *Plasma and Controlled Fusion*; Uman, *Introduction to Plasma Physics*; Glasstone and Loveberg, *Controlled Thermonuclear Reactions*. PREREQUISITE: PH 4661.

PH 4681 ADVANCED PLASMA PHYSICS I (3-0). Topics covered will be related to research problems in progress or contemplated and will depend somewhat on students enrolled. Possible topics are: diffusion in plasma, turbulence and fluctuations in plasmas, radiation from plasmas, propagation of various types of plasma waves. Use will be made of current scientific literature. TEXTS: Allis Buchsbaum and Bers, *Waves in Anisotropic Plasmas*; Kadomtser, *Plasma Turbulence*; Lecture Notes. PREREQUISITE: PH 4662.

PH 4682 ADVANCED PLASMA PHYSICS II (3-0). A continuation of PH 4681 with emphasis on the current scientific literature. PREREQUISITE: PH 4681.

PH 4685 ATOMIC SPECTROSCOPY (3-0). Spectroscopic instrumentation, vector model of the atom and applications to complex spectra, line broadening problems and applications to diagnostic measurements in plasma systems, selected topics in astrophysics. TEXTS: Kuhn, *Atomic Spectra*; Griem, *Plasma Spectroscopy*. PREREQUISITE: PH 3651 and consent of Instructor.

PH 4686 ATOMIC COLLISION PROCESSES (3-0). Atomic interactions of interest in low density gases, classical and quantum description of the collision process. Selected applications from the physics of the upper atmosphere, effects of solar radiation on atmospheric and interplanetary gases. Experimental techniques and instrumentation. TEXT: McDaniels, *Collision Phenomena in Ionized Gases*. PREREQUISITE: PH 3651 and consent of Instructor.

PH 4750 RADIATION EFFECTS IN SOLIDS (3-2). The effects of nuclear radiation and the effects of shock waves on the properties of solids: interaction of radiation with solids, displacement of atoms in solids and the effects on solid state properties; effects on electrons in solids; effects of shock compression of solids, behavior beyond the elastic limit, phase changes. Part of the laboratory will be used for a seminar. TEXTS: Dienes and Vineyard, *Radiation Effects in Solids*; Instructor's Notes. PREREQUISITES: PH 4760, PH 3461.

PH 4751 PHYSICS OF SOLIDS I (3-0). Theory of the structure and properties of solids: crystal symmetry and the anisotropy of physical properties, binding in solids, imperfections, lattice vibrations, lattice specific heat, magnetic properties. TEXT: Kittel, *Introduction to Solid State Physics*. PREREQUISITES: PH 3561, PH 3651, PH 3951 or PH 4971.

PH 4752 PHYSICS OF SOLIDS II (3-2). A continuation of PH 4751 with laboratory experiments relating to both terms. Electronic properties of solids: free electron theory,

transport properties, band theory, Brillouin zones, effective mass, physics of semi-conductors and solid state devices, optical properties, super-conductivity, ferromagnetism. TEXTS: Kittel, *Introduction to Solid State Physics*; Ziman, *Electrons in Metals*. PREREQUISITE: PH 4751.

PH 4760 SOLID STATE PHYSICS. (4-2). Fundamental theory and related laboratory experiments dealing with solids: crystals, binding energy, lattice vibration, dislocations and mechanical properties, free electron theory, band theory, properties of semiconductors and insulators, magnetism. TEXT: Kittel, *Introduction to Solid State Physics*, 3rd ed. PREREQUISITE: PH 3651.

PH 4781 ADVANCED SOLID STATE PHYSICS I (3-0). Detailed studies of selected topics in solid state physics. The material selected will be chosen to meet current requirements. PREREQUISITES: PH 4752 or consent of Instructor.

PH 4782 ADVANCED SOLID STATE PHYSICS II (3-0). Detailed studies of selected topics in solid state physics. PH 4781 and PH 4782 are normally given in alternate years. PREREQUISITES: PH 4752 or consent of Instructor.

PH 4790 THEORY OF QUANTUM DEVICES (3-0). Theory of the operation of electronic devices depending on energy states and the quantum nature of radiation; topics in quantum mechanics, spin resonance, rotating coordinates, relaxation times, internal fields: application to specific electronic devices, parametric amplifiers, magnetic instruments. TEXTS: Siegman, *Microwave Solid State Masers*; Pake, *Paramagnetic Resonance*; Heavens, *Optical Masers*; Bloembergen, *Nonlinear Optics*. PREREQUISITES: PH 3641 or PH 3651.

PH 4851 NUCLEAR PHYSICS (4-2). Nuclear forces; the deuteron; low energy scattering. Nuclear models; spin and moments. Nuclear reactions; fission; reactors. Weak interactions; B-decay. TEXTS: Enge, *Introduction to Nuclear Physics*; Elton, *Introductory Nuclear Theory*. PREREQUISITES: PH 3652, PH 3352, PH 3951.

PH 4881 ADVANCED NUCLEAR PHYSICS I (3-0). Selected topics in nuclear and particle physics. The particular subjects covered will depend on the needs of the students and choice of the instructor. PREREQUISITES: PH 4851, PH 3951, or PH 4971.

PH 4882 ADVANCED NUCLEAR PHYSICS II (3-0). A continuation of PH 4881. PREREQUISITE: PH 4881.

PH 4885 REACTOR THEORY (3-0). The diffusion and slowing down of neutrons. Homogeneous thermal reactors; time behavior; reactor control. Multigroup theory. Heterogeneous systems and perturbation theory. TEXTS: Glasstone and Edlund, *The Elements of Nuclear Reactor Theory*; Murray, *Nuclear Reactor Physics*. PREREQUISITE: PH 4851.

PH 4971 QUANTUM MECHANICS I (3-0). Matrix formulation of quantum mechanics. Stationary states of the square well, the harmonic oscillator, and the hydrogen atom. TEXTS: Dirac, *Quantum Mechanics*; Schiff, *Quantum Mechanics*. PREREQUISITES: PH 3651 and PH 4171.



PH 4972 QUANTUM MECHANICS II (3-0). Addition of angular momenta. Time independent and time dependent perturbation theory. Partial wave analysis of scattering. Identical particles and spin. TEXTS: Dirac, *Quantum Mechanics*; Schiff, *Quantum Mechanics*. PREREQUISITE: PH 4971.

PH 4973 QUANTUM MECHANICS III (3-0). Atoms and molecules, properties and solutions of relativistic particle wave equations. TEXTS: Schiff, *Quantum Mechanics*; Bjorken and Drell, *Relativistic Quantum Mechanics*. PREREQUISITE: PH 4972.

PH 4981 QUANTUM FIELD THEORY I (3-0). Quantization of scalar, spinor, and (massless) vector fields. TEXT: Schweber, *Introduction to Relativistic Quantum Field Theory*. PREREQUISITES: PH 4371 and PH 4973.

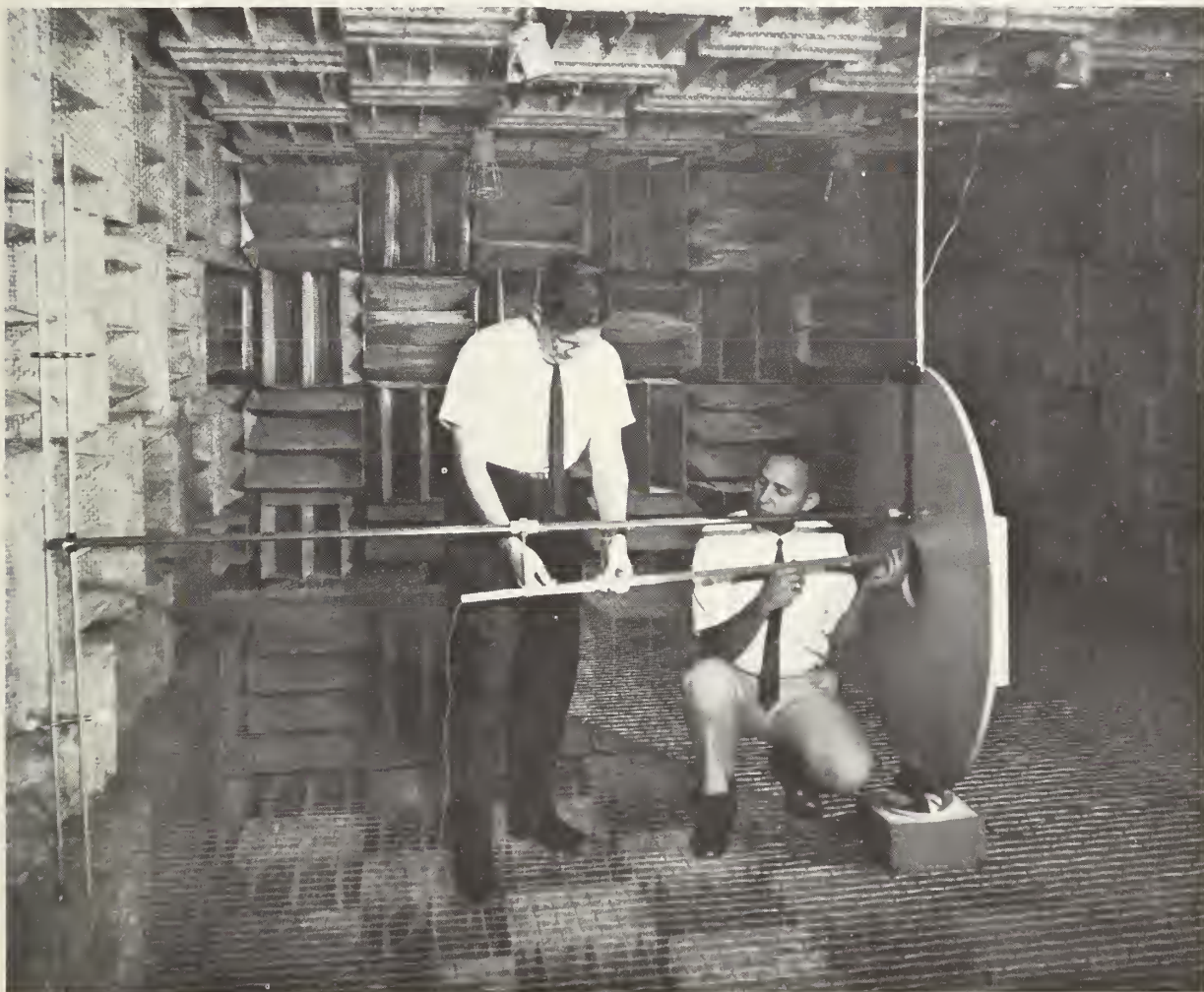
PH 4982 QUANTUM FIELD THEORY II (3-0). Interacting Fields. The S-matrix and renormalization. Strong,

electromagnetic, and weak interactions. Introduction to dispersion relations. TEXT: Schweber, *Introduction to Relativistic Quantum Field Theory*. PREREQUISITE: PH 4981.

PH 4991 RELATIVITY AND COSMOLOGY (3-0). Introduction to the general theory of relativity. The three classical tests of the general theory. The Schwarzschild singularity. Cosmological models. TEXTS: Eddington, *The Mathematical Theory of Relativity*; Bondi, *Cosmology*. PREREQUISITE: PH 4371.

PH 4993 PHYSICAL GROUP THEORY (3-0). Invariance of quantum mechanical systems to certain groups of transformations. Topics to be selected from finite rotation groups and crystal symmetries, the continuous rotation group in three dimensions, transformation groups associated with elementary particle symmetries. PREREQUISITE: PH 4972.

PH 4998 READING IN ADVANCED PHYSICS (2-0). Supervised reading from the periodicals in fields of advanced physics selected to meet the needs of the student.



*Acoustic Measurements in the Anechoic Chamber of the Physics Department*

## NAVY MANAGEMENT SYSTEMS CENTER

EDWARD JOSEPH O'DONNELL, Rear Admiral, U.S. Navy; Director; B.S., Naval Academy, 1929; Naval Postgraduate School, 1939.

HERMAN PAUL ECKER, Professor; Asst. Director (1957)\*; B.A., Pomona College, 1948; M.A., Claremont Graduate School, 1949; Ph.D., (pending).

MILES EDMISTON TWADDELL, Commander, U.S. Navy; Assistant Professor (1965); B.S., Ohio State Univ., 1959; M.S., Naval Postgraduate School, 1962.

ROSCOE LLOYD BARRETT, JR., Lieutenant Colonel, U.S. Marine Corps; Assistant Professor (1966); B.J., Univ. of Missouri, 1947; M.S., Naval Postgraduate School, 1964.

FRANK ELMER CHILDS, Professor (1965); B.A., Willamette Univ., 1934; M.B.A., Univ. of Southern California, 1936; Ph.D., Univ. of Minnesota, 1956.

ROGER STERLING CLARK, Lieutenant Commander, U.S. Navy; Assistant Professor (1966); B.S., Univ. of California at Berkeley, 1953; M.S., Naval Postgraduate School, 1966.

JOHN EDWARD DAWSON, Associate Professor (1966); B.A., The Principia College, 1953; M.P.A., Syracuse Univ., 1954; Ph.D. (pending).

WILLIAM ALAN MAUER, Associate Professor (1966); A.B., San Jose State, 1955; M.S., Agricultural and Mechanical College of Texas, 1957; Ph.D., Duke Univ., 1960.

DONALD BLESSING RICE, JR., Captain, U.S. Army; Assistant Professor (1965); B.S., Univ. of Notre Dame, 1961; M.S., Purdue Univ., 1962; Ph.D., 1965.

CHARLES ERNEST TYCHSEN, Lieutenant Colonel, U.S. Air Force; Associate Professor (1965); B.S., Princeton Univ., 1943; M.S., Air Force Institute of Technology, 1953; M.B.A., Ohio State Univ., 1956; Ph.D., Univ. of Maryland (pending).

IVON WILLIAM ULREY, Professor (1966); B.S., Ohio State Univ., 1931; M.B.A., New York Univ., 1937; Ph.D., Ohio State Univ., 1953.

CARLTON LEROY WOOD, Professor (1966); B.A., Univ. of Washington, 1932; M.A., Columbia Univ., 1944; Ph.D., Heidelberg Univ., 1936.

\* The year of joining the Postgraduate School Faculty is indicated in parentheses.

## DEFENSE MANAGEMENT SYSTEMS COURSE

The Navy Management Systems Center was established at the Naval Postgraduate School to conduct the Defense Management Systems Course. Faculty members are a part of the regular faculty of the Postgraduate School to insure the academic excellence of the program.

The Planning-Programming-Budgeting System developed since 1961 by the Office of the Secretary of Defense has provided a framework for examining various force mixes, allocation of resources, and relationships to military capabilities.

The objective of the Defense Management Systems Course is to provide an appreciation of the concepts, principles, and methods of defense management as they concern planning, programming, budgeting, and related activities. The course covers force planning, and DoD programming, program budgeting, and their interrelationships with resource management systems. Emphasis is placed on the analytical aspects of management; including requirements studies, systems analysis, cost/effectiveness, cost estimating and analysis.

Students are not expected to become experts or technicians in the various disciplines and subjects included in the curriculum. The objectives are to provide orientation on the overall functioning of the defense management process, insights as to what defense management requires in the way of inputs and analyses for decision making, understanding of the principles, methods and techniques used, and awareness of the interfaces between the management requirements of the DoD components and the Office of the Secretary of Defense.

## CALENDAR — Academic Year 1967-68

16 July - 11 August 1967 . . . . .	Class 68-1
4 September - 29 September 1967 . . . . .	Class 68-2
16 October - 10 November 1967 . . . . .	Class 68-3
27 November - 20 December 1967 . . . . .	Class 68-4
*14 January - 9 February 1968 . . . . .	Class 68-5
*25 February - 22 March 1968 . . . . .	Class 68-6
*7 April - 13 April 1968 . . . . .	Flag/General
*28 April - 24 May 1968 . . . . .	Class 68-7
*9 June - 3 July 1968 . . . . .	Class 68-8

\* Tentative dates.

# POSTGRADUATE SCHOOL STATISTICS GRADUATES BY YEARS

	1946- 1950	1951- 1955	1956- 1960	1961- 1965	1966	Total
Bachelor in Arts .....	.....	.....	.....	180	113	293
B.S. in Aeronautical Engineering .....	73	212	212	181	34	712
B.S. in Chemistry .....	.....	.....	3	3	1	7
B.S. in Communications Engineering .....	.....	.....	42	95	24	161
B.S. in Electrical Engineering .....	62	115	98	253	43	571
B.S. in Engineering Electronics .....	94	177	92	172	42	577
B.S. in Environmental Science .....	.....	.....	.....	12	.....	12
B.S. in Management .....	.....	.....	.....	53	1	54
B.S. in Mechanical Engineering .....	43	116	52	82	24	317
B.S. in Meteorology .....	16	104	77	108	21	326
B.S. in Physics .....	.....	15	36	75	16	142
Bachelor of Science .....	.....	56	94	583	117	850
Total Baccalaureate Degrees .....	288	795	706	1,797	436	4,022
M.S. in Aeroelectronics .....	.....	.....	.....	4	.....	4
M.S. in Aeronautical Engineering .....	.....	.....	.....	36	24	60
M.S. in Chemistry .....	.....	.....	16	5	9	30
M.S. in Communications Engineering .....	.....	.....	.....	.....	6	6
M.S. in Materials Science .....	.....	.....	.....	5	4	9
M.S. in Electrical Engineering .....	7	34	46	86	21	194
M.S. in Engineering Electronics .....	68	120	78	104	19	389
M.S. in Management .....	.....	.....	.....	406	89	495
M.S. in Management/Data Processing .....	.....	.....	.....	22	22	44
M.S. in Mechanical Engineering .....	20	36	48	49	11	164
M.S. in Meteorology .....	23	19	40	53	18	153
M.S. in Operations Research .....	.....	.....	.....	63	45	108
M.S. in Physical Oceanography .....	.....	.....	.....	.....	12	12
M.S. in Physics .....	.....	25	104	135	23	287
Master of Science .....	.....	17	65	102	15	199
Total Master's Degrees .....	118	251	397	1,070	318	2,154
Aeronautical Engineer .....	.....	.....	.....	4	6	10
Doctor of Philosophy .....	.....	.....	1	14	7	22
TOTAL DEGREES .....	406	1,046	1,104	2,885	767	6,208



## GRADUATES OF THE POSTGRADUATE SCHOOL 1966

**DIPLOMAS OF COMPLETION,  
ENGINEERING SCIENCE**

ALMBERG, Francis J., LCDR, USN  
 COOPER, Tommy G., LCDR, USN  
 COUGHLIN, Daniel T., Jr., LT, USN  
 GREGORY, Carl W., LT, USN  
 HALLOWELL, Benjamin R., Jr., LT, USN  
 JOHNSON, Oren D., LCDR, USN  
 KORNEGAY, Robert R., LT, USN  
 LOVE, Everette K., Jr., LTJG, USNR  
 McBRIDE, Thomas K., LCDR, USN  
 McNABB, John M., LT, USN  
 O'BRIEN, George E., LCDR, USN  
 RUCKERSFELDT, George E., LT, USN

**DIPLOMAS OF COMPLETION  
MANAGEMENT**

BESIO, Louis F., LCDR, USN  
 CULBERT, Joseph M., Jr., LCDR, USN  
 DiLORENZO, Julia J., LCDR, USN  
 ERWIN, Donald E., LCDR, USN  
 FLOWER, Norman L., LCDR, USN  
 GOETZE, Warren K., LT, USN  
 HARROP, Robert D., LCDR, USN  
 HIRSCHY, Henry E., Jr., LCDR, USN  
 HOWE, Donald K., LCDR, USN  
 JORDAN, William T., LT, USN  
 McDANIEL, Clarence L., CDR, USN  
 McKEE, Robert X., LCDR, USN  
 McKEOWN, William G., LCDR, USN  
 ROUNDTREE, Jack L., LCDR, USN  
 SHIPLEY, Carl N., LCDR, USN  
 ZIERDT, Lucy E., LCDR, USN

**DIPLOMAS OF COMPLETION  
MANAGEMENT/DATA PROCESSING**

BALLEW, Richard F., Jr., LCDR, USN  
 BRADBURY, John I., LCDR, USN  
 O'CONNELL, Daniel J., LCDR, USN

**DIPLOMAS OF COMPLETION  
TECHNICAL CURRICULUM**

GLASER, Francis E., LT, USN  
 KRATCH, David A., LCDR, USN  
 LIVESEY, James E., LT, USN  
 McCORD, Howard E., Jr., LT, USN  
 NEISH, John F., LT, USN  
 NEWCOMB, James W., Jr., LCDR, USN  
 SCHONEMAN, Elmer C., LT, USN  
 STIBLER, Robert W., LT, USN  
 VOLLMER, Robert J., CDR, USN

**BACHELOR OF ARTS**

ARNOLD, Robert B., LCDR, USN  
 ARTIM, Ronald N., LT, USN  
 ASHMORE, Jackie K., CDR, USN  
 BARTLETT, Frederick R., LCDR, USN  
 BECK, Richard E., LCDR, USN  
 BLENKHORN, James M., LT, USN  
 BOLES, Richard L., LCDR, USN  
 BRADLEY, Carlton "S," LT, USN  
 BREAUX, Fred J., LCDR, USN  
 BROOKS, Darrell H., LCDR, USN  
 BURGESS, Harold E., Jr., LCDR, USN  
 BURLESON, Frank M., LCDR, USN  
 BUTTS, Maurice R., LT, USN  
 CAGLE, George F., LT, USN  
 CALHOUN, John F., LT, USN  
 CAMPBELL, Robert J., LCDR, USN  
 CANTLION, Henry C., LCDR, USN  
 CANTWELL, Richard B., LCDR, USN  
 CHAPMAN, Melvin L., CDR, USN  
 CULBERTSON, Wylie J., LT, USN  
 DARNAUER, David E., LT, USN  
 DEAN, Bill C., LCDR, USN  
 deBOXTTEL, Lawrence L., Jr., LCDR, USN  
 DIXON, Jewel L., Jr., LCDR, USN  
 DODD, James R., LCDR, USN  
 DOLAN, William R., LCDR, USN  
 ELDREDGE, Floyd W., LT, USN  
 ENGLISH, Francis W., Jr., LCDR, USN  
 EYRES, Thomas D., LCDR, USN  
 FALCONER, Alastair S., LCDR, USN  
 FEND, Clarence E., LCDR, USN  
 FISCHER, Herman V., Jr., LCDR, USN  
 FLATLEY, John E., LCDR, USN  
 FLORKO, Donald J., LCDR, USN  
 FOLEY, Jerold W., LCDR, USN  
 FRANKS, Richard N., LT, USN  
 FRENCH, Douglas "E," LCDR, USN  
 GEROW, Francis W., LCDR, USN  
 GRIMES, Thomas W., LCDR, USN  
 HALLIER, Manual A., LT, USN  
 HARMON, Jimmy J., LT, USN  
 HARRIS, James W., LCDR, USN  
 HARRIS, William R., LCDR, USN  
 HAWKINS, Sam II., LCDR, USN  
 HELMS, Ronald L., LCDR, USN  
 HOFF, Michael G., LT, USN  
 HOLLINGSWORTH, Robert L., LCDR, USN  
 HORTON, Robert L., LCDR, USN  
 HUNTER, Herbert P., LCDR, USN  
 JOHNSON, Omer L., LT, USN  
 JONES, John E., CDR, USN  
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 BRYANT, William R., CDR, USN  
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 DONNELLAN, Robert I., LT, USN  
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 HOWE, Donald L., LT, USN  
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# INDEX

Academic Standards . . . . .	16	Laboratory Facilities . . . . .	22
Admissions Procedures . . . . .	16	Law . . . . .	61, 64
Advanced Science Curricula . . . . .	28	Lecture Program . . . . .	18
Aeronautical Engineering Curricula . . . . .	29	Libraries . . . . .	21
Aeronautics Department . . . . .	71	Literature . . . . .	94
Aviation Safety Officer Program . . . . .	77		
		Management and Industrial Engineering . . . . .	61, 64
Baccalaureate Programs . . . . .	37	Management . . . . .	79
Bachelor of Arts . . . . .	37, 92	Management Curricula . . . . .	51
Bachelor of Science . . . . .	37	Material Science and Chemistry Department . . . . .	95
Biology . . . . .	84	Materials . . . . .	98
Business Administration . . . . .	61, 62	Mathematics Department . . . . .	101
Business Administration and Economics Department . . . . .	78	Mechanical Engineering (CEC) . . . . .	61, 64
		Mechanical Engineering Department . . . . .	109
Calendar . . . . .	9	Metallurgical Engineering . . . . .	61, 65
Chemistry and Chemical Engineering . . . . .	96	Meteorology . . . . .	114
Civil Engineering (Advanced) . . . . .	61, 63	Meteorology and Oceanography Department . . . . .	113
Communications . . . . .	85	Mission of the Postgraduate School . . . . .	3
Communications, Staff . . . . .	41		
Computer Facilities . . . . .	19	Naval Auxiliary Landing Field . . . . .	16
Computer Science . . . . .	82, 85, 102	Naval Construction and Engineering . . . . .	61, 65
Computer Science Curriculum . . . . .	49	Naval Engineering Curricula . . . . .	46
Construction Engineering . . . . .	61, 63	Naval Management and Operations Analysis Curricula . . . . .	49
Curricula at Other Universities . . . . .	61	Navy Management Systems Center . . . . .	130
Curricula at the Postgraduate School . . . . .	27	Nuclear Engineering (Advanced) . . . . .	61, 65
		Nuclear Engineering (Effects) . . . . .	54
Data Processing Curriculum . . . . .	50	Nuclear Power Engineering (CEC) . . . . .	61, 65
Defense Management Systems Course . . . . .	130		
Degrees, Accreditation and Standards . . . . .	16	Oceanography . . . . .	116
Dependent Information . . . . .	15	Oceanography (Civilian Universities) . . . . .	61, 66
Distinguished Alumni . . . . .	11	Operations Analysis Curriculum . . . . .	51
		Operations Analysis Department . . . . .	118
Electrical Engineering (CEC) . . . . .	61, 63	Ordnance Engineering Curricula . . . . .	54
Electrical Engineering Department . . . . .	83	Ordnance Systems . . . . .	55
Electronics and Communications Engineering Curricula . . . . .	39	Organization and Functions of the Postgraduate School . . . . .	14
Engineering Electronics (CEC) . . . . .	61, 63		
Engineering Science . . . . .	91	Petroleum Administration and Management . . . . .	61, 66
Engineering Science Curricula . . . . .	42	Petroleum Engineering (CEC) . . . . .	61, 66
English . . . . .	92	Physics Department . . . . .	123
Environmental Sciences Curricula . . . . .	44	Political Science . . . . .	61, 66
		Procurement Management . . . . .	61, 66
Facilities of Postgraduate School . . . . .	15	Proficiency Flying . . . . .	16
Financial Management . . . . .	61, 63	Probability and Statistics . . . . .	107, 122
		Psychology . . . . .	94
General Information . . . . .	13 - 18	Public Relations . . . . .	61, 67
Geography . . . . .	92		
Government . . . . .	92	Religion . . . . .	61, 67
Government and Humanities Department . . . . .	92	Retailing . . . . .	61, 67
Graduates by Years . . . . .	131		
Graduates of 1966 . . . . .	132	Speech . . . . .	94
		Student and Dependent Information . . . . .	15
History . . . . .	93	Subsistence Technology . . . . .	61, 67
History of Postgraduate School . . . . .	13	Superintendent's Staff . . . . .	7, 8
Honors, Academic . . . . .	17	Systems Inventory Management . . . . .	61, 67
Hydrographic Engineering (Geodesy) . . . . .	61, 64		
		Transportation Management . . . . .	61, 67
Industrial Engineering and Management . . . . .	61, 64		
Information, General . . . . .	13 - 18	Underwater Physics Systems Curriculum . . . . .	59
International Law . . . . .	61, 64		
International Relations . . . . .	61, 64		

















